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JOURNAL OF PALEONTOLOGY

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CONTENTS

Tertiary Foraminifera from the Willapa River Valley of southwest Washington ... *Weldon W. Rau* 417

Lower Mississippian ammonoids of Missouri .... *A. K. Miller* and *Charles Collinson* 454

Upper Cretaceous Foraminifera from the Carlsbad area, San Diego County, California ... *Orville L. Bandy* 488

Upper Paleozoic microfossils from Stevens County, Washington ... *Kenneth P. McLaughlin* and *Merton E. Simons* 514

Size relations in the limb bones of *Buettneria perfecta* ... *Russell Olsen* 520

A new instrument for measuring fossils ... *Robert E. Sloan* 525

New genera and subgenera of Radiolarida ... *Arthur S. Campbell* 527

Notes on thin sectioning of smaller Foraminifera ... *Cesare Emiliani* 531

PALEONTOLOGICAL NOTES ... 533

NOMENCLATURAL NOTES ... 537

BIBLIOGRAPHIC NOTE ... 540

NOTICE ... 541

REVIEWS ... 542

SOCIETY RECORDS AND ACTIVITIES

Reports and minutes of the twenty-fifth annual meeting of the Society of Economic Paleontologists and Mineralogists ... 544

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VOLUME 25 JULY, 1951 NUMBER 4

TERTIARY FORAMINIFERA FROM THE WILLAPA RIVER VALLEY OF SOUTHWEST WASHINGTON

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ABSTRACT—Tertiary sediments more than 5500 feet thick are exposed along a 7-mile portion of the Willapa River Valley in southwest Washington. These strata are varied lithologically but are mostly siltstones and sandstones. They carry numerous Foraminifera of which 81 species belonging in 39 genera of 16 families are discussed and illustrated. These fossils appear to indicate a rather uniform marine environment of an off-shore shallow to intermediate depth. The fauna further suggests slightly warmer conditions than those now existing in bays of the Pacific Northwest. Foraminiferal evidence appears to indicate the presence of at least partial equivalents of the Cowlitz, Keasey-Bastendorf, Lincoln, Blakeley and Astoria formations. It is therefore probable that the fossiliferous strata under consideration range in age from upper Eocene to lower Miocene.

INTRODUCTION

THERE has been increasing need in recent years for the correlation of rather widely separated Tertiary outcrops in the Pacific Northwest. Important results have been accomplished by the study of megafossils but these are rare in many outcrops. Furthermore, in subsurface work large fossils are either so few or so fragmented by the drilling process that they are of little value. Foraminifera, on the other hand, occur to some extent in many of the Tertiary deposits of the region, and because of their small size and excellent preservation they have proved to be very useful.

A number of foraminiferal faunas have been recorded in this region, but from areas that are widely separated both geographically and stratigraphically. Moreover, the nearest comparable Tertiary beds which have been correlated on the basis of Foraminifera are in California. The distance is so great that environmental conditions almost certainly were not the same, particularly because of considerable difference in latitude.

It is apparent that there is need for the study of Foraminifera from an essentially continuous Tertiary section in the Pacific Northwest. From such an investigation we could more nearly determine the proper stratigraphic position of faunas already described as well as those to be recorded in the future. Sections necessary for this type of study are rare, chiefly because of the large amount of cover generally encountered in the Northwest. The strata in the Willapa Valley, however, although concealed at occasional intervals, are well enough exposed in the river bed to furnish an almost continuous section of much of the Tertiary.

In this paper the writer illustrates and discusses the stratigraphical significance of

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Foraminifera from a sequence of Tertiary sediments in the Willapa River Valley. A traverse was made down the valley, starting about a thousand feet above the mouth of Fish Trap Creek and continuing downstream to the northwest corner of section 2, T. 13 N., R. 8 W., Willapa quadrangle, Pacific County, Washington. The linear distance involved is over 7 miles, and more than 5500 feet of sedimentary strata can be observed. Foraminifera or other fossils are not common in certain parts of the section and several portions of it are concealed beneath soil and alluvium, but the foraminiferal samples obtained suggest a stratigraphic range from probable upper Eocene at the base of the section to lower Miocene at the top.

STRUCTURE

In general the strata of the Willapa valley strike west of north 50° to 60° and dip between 20° and 30° to the northeast. The Willapa River flows a little west of north over these dipping beds and thus in a downstream traverse strata of progressively younger age are generally encountered. The river descends from about 150 feet above sea level at the southern end of the area to approximately 25 feet in the extreme north. Because of the great horizontal distance involved, difference in river level from station to station is not important, and therefore the river surface has been taken as a mean level, and all samples were collected as near it as possible.

There are several deviations from the general structure previously mentioned (see fig. 1). In the northern part of the area, where the upper portion of the section is exposed, there is a small anticline and just south of it a syncline. Both structures have a general strike similar to that of the region. Slightly north of the central part of the area the beds are cut by a high angle fault striking northeast-southwest. Although this fault is quite apparent, it probably has no great displacement, for foraminiferal faunas from both sides of it are essentially the same. Upstream from this fault and about half way to the southern limit of the area there is another noticeable flexure which may be faulted, but there is no evidence to indicate great displacement. In addition to these major irregularities there are local deviations. Most of these occur in the southern portion of the area or where the lower part of the section is exposed. There the structure is somewhat complicated by a number of faults and some folding. In that part of the area it is most difficult to interpret the structure with reasonable certainty as exposures are restricted to a few cliffs along the river or places in the river bed where they are not concealed by alluvium and are accessible. Therefore, only the general structure of that portion of the area was determined, and interpretations and measurements of this part of the section were necessarily based largely on the regional structure.

LITHOLOGY

While in the field, the writer was primarily interested in securing fossiliferous samples and did not collect material for a systematic laboratory analysis of the sediments. Nevertheless, the following generalizations, based almost entirely on field observations, may be helpful to future workers in the area.

The Willapa Valley beds consist largely of gray, massive siltstones and sandstones varying in grain size and amount of induration (fig. 2). The composition varies considerably in local portions of the section and some beds are highly glauconitic, some micaceous, and others contain an abundance of carbonaceous material. Much of this sediment is not well stratified and therefore it is often difficult to determine structure, except where resistant strata occur at intervals within some of the massive zones. Some strata contain very few recognizable fossils, but molluscan and crustacean remains are abundant in other beds. Some Foraminifera are present in almost all of the strata.

The lower boundary of the section is defined by brecciated dense igneous material. Lying stratigraphically above this rock are the sedimentary strata with which the present report is concerned. The first 100 feet or so are blue-gray, massive, well indurated, somewhat glauconitic siltstone. No fossils of any kind were obtained from this zone. Stratigraphically above it lie about 400 feet of gray, fine-grained, massive, only slightly indurated, somewhat micaceous siltstone.

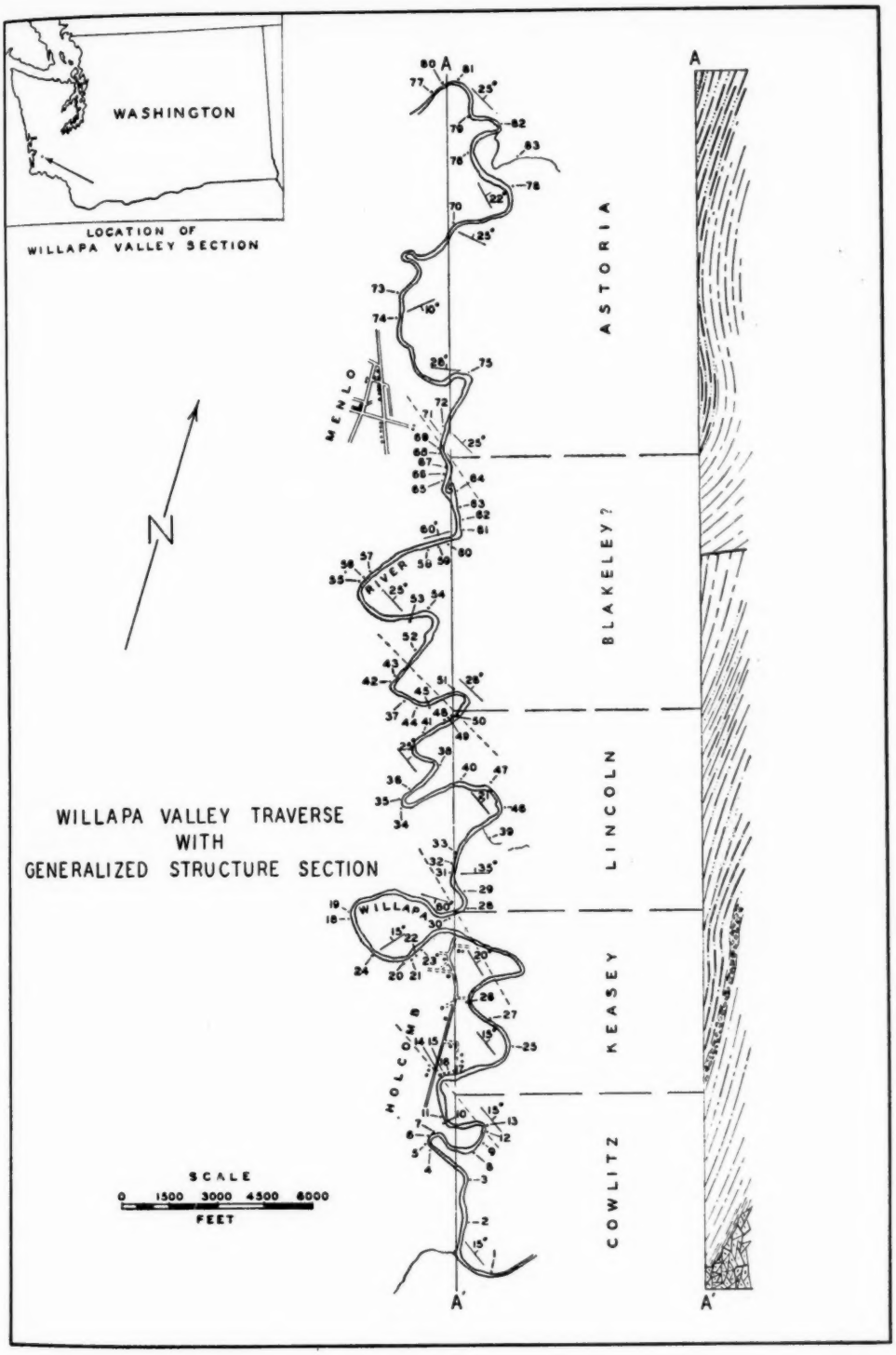
WASHINGTON
LOCATION OF
WILLAPA VALLEY SECTION
WILLAPA VALLEY TRAVERSE
WITH
GENERALIZED STRUCTURE SECTION
SCALE
0 1500 3000 4500 6000
FEET
ASTORIA
BLAKELEY?
LINCOLN
KEASEY
COWLITZ
MENLO
RIVER
WILLAPA
HOLCOMB
A
A'

FIG. *1*

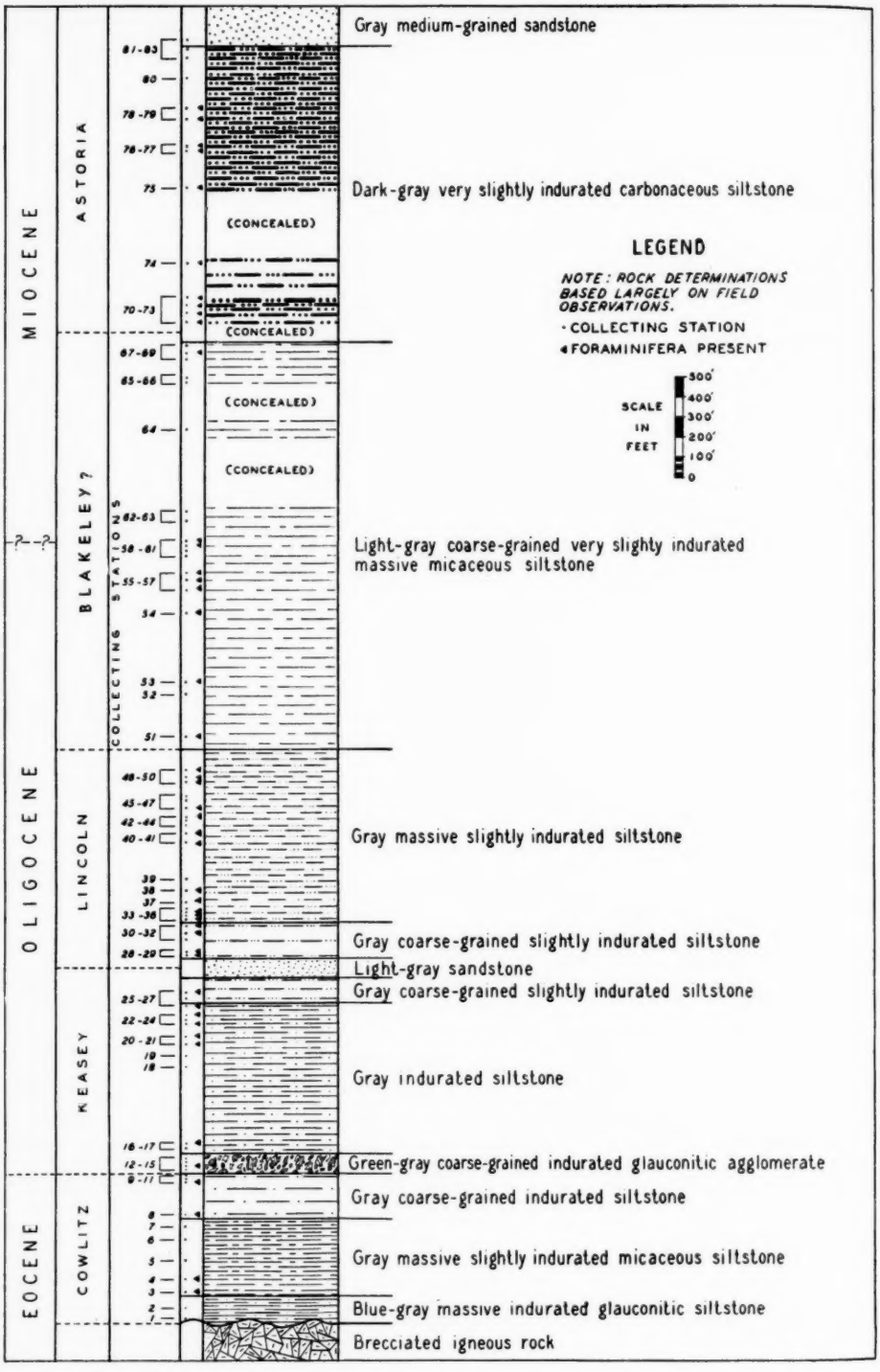

FIG. 2—Columnar section of the Willapa Valley Tertiary.

Foraminifera, as well as molluscs, were obtained from this zone at several localities. These beds are overlain by some 200 feet of gray, noticeably coarser, well indurated siltstone. The Foraminifera secured from this zone as well as those from the underlying beds strongly suggest that these strata are of Cowlitz age. Perhaps the unfossiliferous basal strata are also part of the Willapa Valley Cowlitz equivalent.

Overlying the Cowlitz beds are approximately 100 feet of green-gray, agglomeratic, well indurated, glauconitic, fossiliferous sediments. The fossils secured from them indicate that they probably represent the lowest Keasey equivalent in the Willapa Valley area. About 900 feet of gray, fine-grained, indurated siltstone overlying the agglomeratic beds contain typical Keasey Foraminifera and theretore probably represent the major portion of the Willapa Valley Keasey equivalent.

Light gray sandstone, estimated to be about 100 feet thick, overlies the last described strata. This bed is believed to represent the division between the Keasey and the superjacent Lincoln equivalent of the Willapa Valley. No fossils were obtained from it and therefore it may be of either Keasey or Lincoln age. Gradual decrease in grain size occurs in the overlying sediments which consist of about 1000 feet of gray, very fine-grained material that probably represents most of the Lincoln equivalent in the Willapa Valley. These beds are extremely massive and reveal apparent structure only where infrequent thin, resistant layers are exposed.

At least 1500 feet of sediments noticeably uniform in texture and composition succeed the Willapa Valley Lincoln. Practically all are light gray, moderately fine-grained, massive, micaceous siltstone. They are distinguishable from the Lincoln chiefly because they are generally coarser, quite micaceous, and perhaps more loosely cemented. They may represent the Willapa Valley equivalent of at least part of the Blakeley.

Most of the higher beds are somewhat darker colored, probably because of more abundant carbonaceous material. Such strata are at least 1100 feet thick and they are probably equivalent to the lower part of the Astoria formation. They are overlain by gray, massive sandstone. This division is quite distinct but the beds are conformable and gradation can be observed in several outcrops along the north and east banks of the Willapa River in the north portion of the area.

COMPOSITION OF FAUNA

The Willapa Valley foraminiferal fauna consists of 81 species belonging to 39 genera and 16 families. Of these, 56 are identified with species or varieties previously described; 11 are more or less similar to previously described species; seven are believed to be new species; and seven forms are not well enough preserved to permit a definite identification.

The family Buliminidae is represented by the largest number of genera, species and individuals. In this family the genera *Bulimina*, *Bolivina* and *Uvigerina* contain the majority of the species and individuals. Although the family Lagenidae is represented by nearly as many genera, most of the species and individuals are confined to the genus *Robulus*. The Miliolidae are fairly well represented, but the genus *Quinqueloculina* contains the majority of the species and individuals. The Heterohelicidae are represented only by *Plectofrondicularia*, but there are numerous species of this genus. The remainder of the fauna is somewhat irregularly distributed among 12 families.

ENVIRONMENTAL CONDITIONS

Numerous opinions have been expressed regarding the environment of deposition of the marine Tertiary sediments in the Pacific Northwest, but most writers have agreed that deposition occurred in shallow to intermediate depths. The following are among those who have expressed this general opinion: Etherington (1931), Frizzell and Blackwelder (1933), Cushman and Frizzell (1943), Beck (1943), Detling (1946) and Rau (1948a, b). There are, of course, different interpretations regarding the specific environments of local areas and this is not surprising as undoubtedly local variations occurred during Tertiary time.

It is very difficult to reconstruct ecology solely on the basis of fossils. Most modern Foraminifera apparently exist successfully

under a wide range of temperature and depth conditions, as has been shown by the observations of Norton (1930) and Natland (1933). It is understandable, therefore, that the foraminiferal assemblages under consideration do not point to one or more specific environments although certain generalizations can be made.

Comparison with Norton's work (1930) shows that 19 of the 39 known Willapa Valley foraminiferal genera frequently occur in shallow water (beach to 60 fathoms), 25 occur at intermediate depths (500 to 825 fathoms) and 12 are known from deep water (2000 to 2850 fathoms). Furthermore, of the ten genera found most commonly throughout the section and most likely deposited in their natural environment, six commonly occur in shallow water, six at intermediate depths, and three in deep water. On the whole these comparisons suggest an environment of shallow to intermediate depth.

Inasmuch as several epochs are probably represented by the Willapa Valley sediments (see following section), it would be reasonable to expect some variation in bathymetric conditions during the time that they represent. Depth analysis of the common genera in each formational equivalent of the section, however, fails to reveal any such variation. In fact, the most striking element in these comparisons is the constancy of the ratio which exists between the shallow, intermediate and deep water genera of each formational equivalent and the common genera of each substantiate the conclusion that they accumulated at shallow to intermediate depths.

The fine-grained sediments and thick-shelled molluscs also indicate shallow to intermediate depths. The absence of abundant carbonaceous material and worn shell fragments suggests deposition well off-shore. The uniform nature of the sediments is evidence for the continuity of similar environments. If depth varied appreciably, the shallowest conditions are probably indicated by the Blakeley(?) sediments as they are slightly coarser than almost any of the others.

Records of Recent foraminiferal faunas from Puget Sound (Cushman and Todd, 1947) and the coast of southern California near Long Beach (Natland, 1933) have been analyzed and compared with the Willapa Valley collection. California Foraminifera restricted to depths exceeding that of Puget Sound have been disregarded so that the two modern faunas represent comparable depth ranges. Of the 39 Willapa Valley genera, 30 occur off southern California today but only 16 are present in Puget Sound. This seems to suggest that the Willapa Valley fauna records temperatures more like those of southern California than nearby Puget Sound, but the California fauna consists of 72 genera while that of Puget Sound has only 38, and the percentage of genera common to each is almost exactly the same. Also, of the ten most abundant Willapa Valley genera, five are common in the California assemblage and four occur frequently in Puget Sound. Therefore, this comparison actually furnishes very little evidence regarding temperature and it can only be concluded that the Willapa Valley fauna indicates subtropical to temperate conditions.

A few species in the Willapa Valley assemblage exist in Pacific Coast waters of today. Natland (1933) recorded seven species from southern California which also occur in the Willapa Valley collection. Of these species, *Buliminella subfusiformis*, *Cassidulina pulchella* and *Eponides umbonatus* are restricted there to fairly deep water (usually 1000 to 2900 feet). The other four species, *Globigerina bulloides*, *Nonionella miocenica*, *Pullenia salisburyi* and *Sigmoilina tenuis*, are either pelagic or widespread bathymetrically and therefore they are of very little value for depth comparisons. By way of contrast, only two Willapa Valley species, *Nonionella miocenica* and *Pullenia salisburyi*, are known from Puget Sound (Cushman and Todd, 1947) and both of these species occur in the southern California assemblage. These occurrences suggest that the Willapa Valley fauna may have inhabited a rather deep subtropical environment.

It is apparent that only generalized ecological interpretations are possible, but on the whole the Willapa Valley fauna and sediments suggest rather uniform off-shore marine conditions at shallow to intermediate depth in seas perhaps slightly warmer than the waters of present day Puget Sound.

CORRELATIONS

Probable equivalents of several previously known Pacific Northwest Tertiary zones or formations are believed to be represented in the Willapa Valley section. They are as follows:

Cowlitz.—The Foraminifera suggest that about 700 feet of strata at the base of the Willapa Valley section (see fig. 2) is equivalent to at least part of the type Cowlitz formation of Lewis County, Washington. Most of the species present in these strata have been recorded previously from the Cowlitz (Beck, 1943). *Robulus holcombensis, R. texanus, Cibicides hodgei* and *Cassidulina globosa* occur with varying frequency in both. These species are not necessarily restricted to sediments of Cowlitz age, but their occurrence is significant, as they usually are found together in upper Eocene sediments. Also, *Saracenaria hantkeni, Vaginulinopsis saundersi, Cibicides natlandi* and *Quinqueloculina goodspeedi* are restricted, for the most part, to the Cowlitz or its approximate equivalent (see fig. 3.) Of these four species, *C. natlandi* and *Q. goodspeedi* probably are most significant as they have been recorded previously only from the type Cowlitz or its probable equivalents. They are generally recognized in the Pacific Northwest as index fossils of the Cowlitz.

Beck (1943, p. 591) compared the Cowlitz fauna of Lewis County with an assemblage from the Coaledo formation of Oregon and found evidence to suggest the correlation of the two formations. Six species present in the lowest part of the Willapa Valley section have been recorded from various parts of the Coaledo formation by Detling (1946) and Cushman, Stewart and Stewart (1947) but *Saracenaria hantkeni,* which is believed to be restricted to the Cowlitz or upper Eocene, is the only one of major significance. Although only a few species are known to be common to the Coaledo and the lower part of the Willapa Valley section, there are many others which are very closely related. This evidence suggests probable correlation of at least part of the Coaledo with the lower part of the Willapa Valley section.

Cushman, Stewart and Stewart (1947) have recorded an assemblage of Foraminifera from the Helmick beds a few miles southeast of Salem, Oregon. They believed that this fauna indicates correlation with the Coaledo and Cowlitz formations. Only three Helmick species, however, occur in the lowest Willapa Valley beds and none is restricted to a very narrow stratigraphic zone.

Beck (1943, p. 591) also pointed out that many Foraminifera from the upper 900 feet of the Tejon formation of California are identical or at least closely similar to those of the Cowlitz in Lewis County. Tejon faunas have not been examined by the writer, but it seems reasonable to assume that the lower part of the Willapa Valley section probably correlates with the upper Tejon (upper Eocene) of California.

Keasey.—Weaver (1937, p. 162) has recorded the occurrence of a typical Keasey megafauna in the sediments exposed near the town of Holcomb (see fig. 1). Foraminifera from the same general vicinity substantiate Weaver's findings inasmuch as they closely resemble an assemblage illustrated and described from the Keasey formation of Oregon (Cushman and Schenck, 1928). Insofar as the writer has been able to determine, the lowest Keasey equivalent in the Willapa Valley section is a well indurated glauconitic agglomerate (see fig. 2). These beds contain a typical Keasey megafauna, but Foraminifera are rare. The upper limit of the Willapa Valley Keasey is not well defined, but a barren sandstone about 1000 feet above the lowest Keasey equivalent may mark the approximate boundary with the superjacent Lincoln. Typical Keasey Foraminifera were found below this sandstone and the lowest characteristic Lincoln fauna was obtained from the sediments directly above.

A close relationship between the foraminiferal faunas of the Willapa Valley Keasey and the Oregon Keasey is based largely upon numerous identical species. Also, certain species not necessarily restricted to the Keasey or its equivalents suggest correlation with the Oregon Keasey. Typical Lincoln species, such as *Plectofrondicularia packardi multilineata, Cibicides elmaensis* and *Uvigerina cocoaensis,* in association with such Cowlitz species as *Cibicides hodgei, Robulus holcombensis* and *R. becki* suggest an intermediate age.

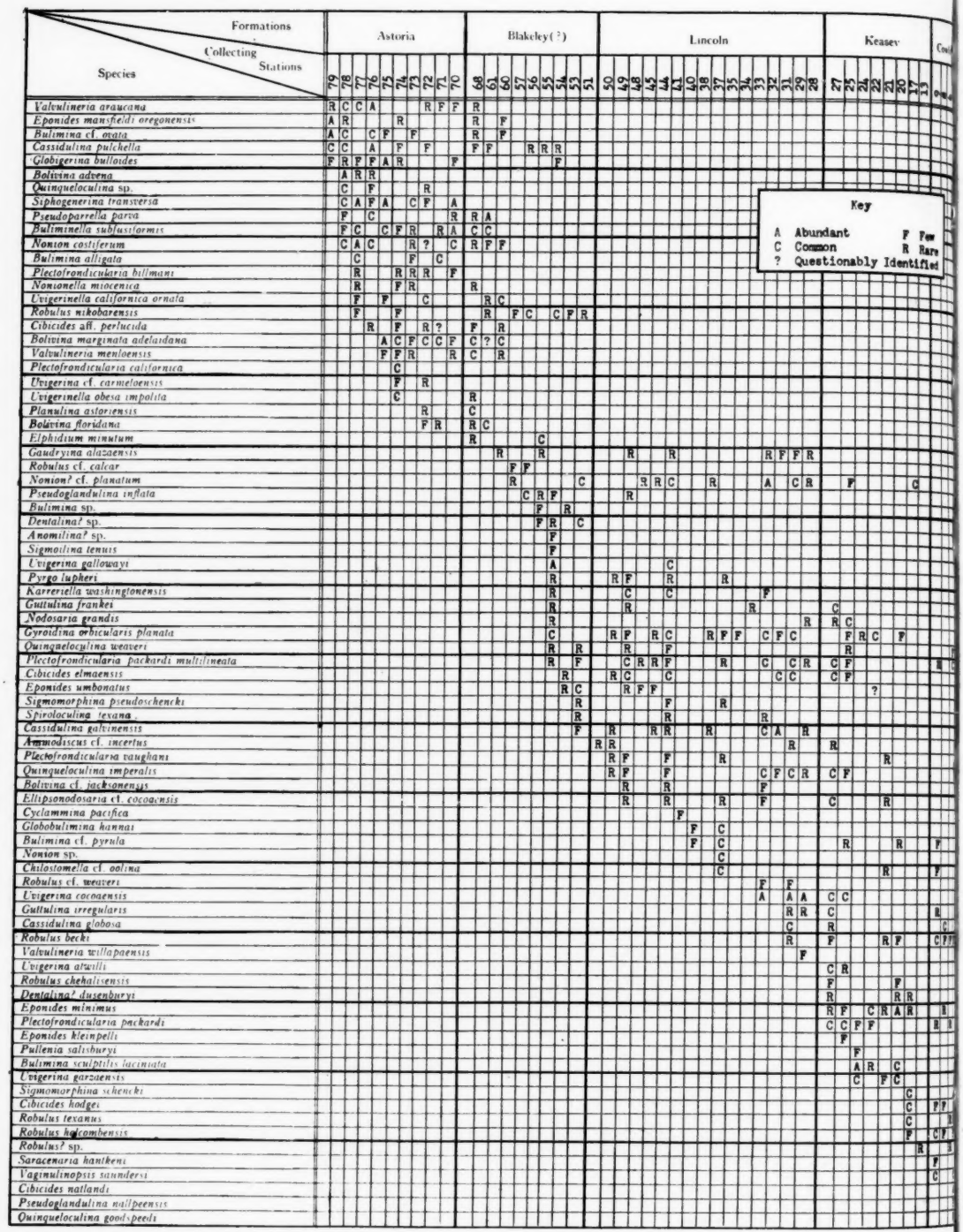

FIG. 3—Distribution of Willapa Valley Foraminifera arranged according to their occurrence.

The Bastendorf formation of Oregon is regarded as being similar to the Keasey in age (Cushman and Schenck, 1928, p. 305). Numerous Willapa Valley species are identical with, and many others are closely related to, those described and illustrated from the Bastendorf (Cushman and Schenck, 1928; Detling, 1946). *Uvigerina atwilli*, *U. garzaensis* and *Bulimina sculptilis laciniata*, which are generally restricted to the Bastendorf or its probable equivalent, are also restricted to the Keasey portion of the Willapa Valley section.

A foraminiferal fauna from the Tumey formation of California (Cushman and Simonson, 1944) contains species which are present in the Willapa Valley Keasey, and many others are similar. *Uvigerina cocoaensis*, together with other species typical of the *U. cocoaensis* zone of Cushman and Simonson, occur in the upper part of the Willapa Valley Keasey. Possibly the upper part of these Washington strata is equivalent to the lower part of the *U. cocoaensis* zone and the lower portion may be at least partially equivalent to the subjacent "transitional zone" of Cushman and Simonson. *Uvigerina garzaensis*, *Bulimina sculptilis laciniata* and *Sigmomorphina schencki* typify the lower Willapa Valley Keasey fauna.

Schenck and Kleinpell (1936, p. 219) and Weaver et al. (1944) include the Bastendorf and Keasey formations in the Refugian stage which, according to them, is probably equivalent to a portion of the upper Eocene or lower Oligocene series of Europe. Schenck and Kleinpell (p. 220) also point out that the lower part of the Refugian is marked by the appearance of *Bulimina sculptilis*, *Plectofrondicularia packardi*, *Uvigerina cocoaensis* and *Cibicides hodgei*. These species are typical of the Willapa Valley Keasey and the age of these strata, therefore, seems to be established.

Lincoln.—According to Weaver (1937, p. 162) a typical Lincoln molluscan fauna occurs in Oligocene strata between the towns of Holcomb and Willapa in the Willapa Valley area. Foraminiferal evidence partially substantiates this belief in that the assemblage obtained between stations 28 and 50 (see fig. 1) has essentially the characteristics of previously described Lincoln faunas (Frizzell and Blackwelder, 1933; Cushman and Frizzell, 1943; Rau 1948a). The Foraminifera obtained from sediments north of station 50, however, cannot all be considered typically Lincoln.

Although the Willapa Valley Lincoln fauna is similar to other Lincoln assemblages, this is not a particularly distinct group of species because almost all of them also occur either in the overlying Blakeley(?) or the subjacent Keasey equivalents. This fauna generally can be distinguished, however, by the absence of a few species typical of the Keasey and others characteristic of the Blakeley(?). More significant probably is the almost complete absence of Astoria species from this fauna. No break in deposition has been recognized either below or above the Willapa Valley Lincoln and these strata appear to be conformable with both the subjacent Keasey and the overlying Blakeley(?).

Some of the species that first appear in the Willapa Valley Lincoln are *Gaudryina alazanensis*, *Uvigerina gallowayi*, *Pyrgo lupheri*, *Karreriella washingtonensis*, *Sigmomorphina pseudoschencki*, *Spiroloculina texana*, *Cassidulina galvinensis*, *Bolivina* cf. *jacksonensis* and *Valvulineria willapaensis*. Most of these have been recorded previously from the Lincoln formation of other areas and, therefore, they are considered to be typical Lincoln forms.

Among the species that make their last appearance in the Willapa Valley Lincoln are *Plectofrondicularia vaughani*, *Quinqueloculina imperalis*, *Bolivina* cf. *jacksonensis*, *Ellipsonodosaria* cf. *cocoaensis*, *Uvigerina cocoaensis*, *Cassidulina globosa* and *Robulus becki*. Most of these are also present in the subjacent Keasey and several range upward from the Cowlitz. The presence of *U. cocoaensis* suggests that the lower portion of the Lincoln may correlate with part of the *Uvigerina cocoaensis* zone but no other species typical of this zone occurs in the Willapa Valley Lincoln. Perhaps this species has a greater stratigraphic range than previously noted.

The Pittsburg Bluff, Tunnel Point and Eugene formations of Oregon, and possibly the lower part of the San Lorenzo formation of California, are all correlated at least in part with the Lincoln formation of Washington by many authorities (Weaver et al.

1944). These formations are considered to represent the upper Refugian stage (Kleinpell, 1938, p. 161). Inasmuch as the writer has not examined collections from these strata, no further substantiating evidence can be submitted, The last appearance of many Keasey and Cowlitz species and first appearance of Blakeley(?) species, however, suggests an intermediate Oligocene age (upper Refugian).

Blakeley(?).—As previously stated, sediments exposed north of station 50 (see fig. 1) do not contain a typical Lincoln foraminiferal fauna and the presence of many Miocene species strongly suggests that these beds are younger than the Lincoln formation. The first Miocene species occur at station 51 and from there northward they become more abundant. For some distance stratigraphically above station 51, however, species common to the Lincoln sediments continue to occur, but in progressively decreasing numbers, and there is a zone at least 1500 feet thick which may be regarded as transitional. Several typical Blakeley species occur in this zone which separates sediments with predominantly Lincoln Foraminifera from those with a characteristic Miocene fauna. This and the stratigraphic position of the type Blakeley in relation to the Lincoln formation in other regions suggests a correlation of these transitional beds with the type Blakeley, but so few typical Blakeley Foraminifera have been found that the true relationship cannot be established definitely at this time. The name Blakeley(?) is used in this report for this zone.

The lower limit of the Willapa Valley Blakeley(?) is defined mainly by the first appearance of Miocene Foraminifera and the upper limit is marked by the last appearance of typical Lincoln species. These strata are rather distinctive as they consist of coarser sediments than most of the others in the section.

The presence of *Uvigerina gallowayi* in the lower portion of this interval suggests that these beds may be equivalent in part to the *U. gallowayi* zone of California. According to Kleinpell (1938, pp. 110, 111), this zone represents the lower portion of the Zemorrian stage which is perhaps the oldest Miocene of the Pacific Coast.

Foraminifera which first appear in the upper portion of the Willapa Valley Blakeley(?), such as *Buliminella subfusiformis*, *Nonion costiferum* and *Uvigerinella obesa impolita* occur in the Nye shale of Oregon and suggest an age approximately equivalent to part of that formation.

As pointed out by Kleinpell (1928, p. 163), the Nye shale contains lower Saucesian Foraminifera. This suggests that the Willapa Valley Blakeley(?) may represent the lower and upper Zemorrian as well as the lower portion of the Saucesian. As can be seen from figure 2, some parts of the section are concealed and all of the Zemorrian and lower Saucesian may not be represented. There is, however, no indication of sudden change, either in the foraminiferal fauna or in the lithology, between any of the stations of the Blakeley(?) zone.

According to Weaver (1937, p. 118), a series of sediments in Monterey County, California, has been referred to as transitional Oligocene-Miocene. It lies immediately above the San Lorenzo formation and beneath the lower Miocene Vaqueros formation, and a part of the Willapa Valley Blakeley(?) may be equivalent to it. These transitional California beds and the Willapa Valley Blakeley(?) occupy similar situations and the foraminiferal fauna recorded by Cushman and Hobson (1935) from the upper one-third of the San Lorenzo formation contains several species that are similar to or identical with some of those in the Willapa Valley Blakeley(?). These species, however, are not restricted to these stratigraphic zones, and therefore their presence is not necessarily indicative of similar age.

According to Kleinpell (1938, p. 163), the San Ramon formation and the Kirker tuff of California appear to be correlatives of the lower Blakeley but none of the Foraminifera of these California beds occur in the Willapa Valley Blakeley(?). Parts of several other Zemorrian and lower Saucesian formations of California, such as the Vaqueros, Temblor and lower Rincon, may be equivalent to the Blakeley(?) of Willapa Valley but precise correlation is uncertain. The areas are widely separated geographically, and probably depositional environments were different. Also, the transitional Blakeley(?) fauna contains no restricted species and several that are common to parts of

the Zemorrian and lower Saucesian of California have wide stratigraphic ranges.

Whether all of the sediments here referred to as Blakeley(?) can be correlated with the type Blakeley remains to be determined. Available foraminiferal evidence and relative stratigraphic position suggest probable partial equivalence but study of the Foraminifera from the upper portion of the type Blakeley is necessary before the true relationship can be established. The Willapa Valley Blakeley(?) contains a transitional fauna and the boundary between the Oligocene and Miocene in the Willapa Valley area probably lies somewhere within these strata.

Astoria.—Weaver (1937, p. 177) stated that the Astoria formation rests upon Oligocene sandy shales immediately south of Mill Creek and that the contact can be followed from near the mouth of Mill Creek northwesterly for some distance along the east side of the Willapa Valley. Etherington (1931, p. 46) was doubtful where to draw this boundary and suggested that the fine-grained sediments directly below the massive sandstone along the Willapa River may be a transitional zone between Oligocene and Miocene. These fine-grained strata are the highest part of the Willapa Valley section studied. Foraminifera are abundant in them and somewhat indicative of age. All previously known species obtained from the beds north of station 69 (fig. 1) and below the massive sandstone occur in the Miocene and almost none of them has been found in the Oligocene Lincoln formation.

Cushman, Stewart and Stewart (1947) have described and illustrated the largest foraminiferal assemblage yet recorded from the Astoria formation of Astoria, Oregon. Of 20 previously known species from the uppermost part of the Willapa Valley section, nine are included in that fauna. These authors have also recorded a small assemblage from the Astoria formation of Agate Beach, Oregon. Four other species found there occur in the upper part of the Willapa Valley section. Also, Kleinpell (1938, p. 70) listed two additional species from the Astoria formation of Astoria which occur in the upper part of the Willapa Valley section. Thus 15 of the 20 previously known foraminiferal species from the upper part of the Willapa Valley section are known from the Astoria formation of Oregon. Most of the other five species occur in Miocene sediments which may correlate, in part at least, with the Astoria. It seems apparent, therefore, that the sediments exposed in the bed of Willapa River north of station 69 and below the overlying sandstone are of Miocene age and should be referred to the Astoria formation.

It is practically impossible at this time to correlate accurately the upper part of the Willapa Valley section with Miocene strata of regions other than western Oregon, where the Astoria is so well developed. Many more species from the upper part of the Willapa Valley section occur in the Saucesian than in any other stage of the California Miocene. According to Kleinpell (1938, p. 163), the type Astoria of Oregon has yielded a typical upper Saucesian fauna and, as previously suggested, the subjacent Blakeley(?) in the Willapa Valley may be, in part at least, lower Saucesian. There is no apparent unconformity between the Willapa Valley Astoria and the underlying Blakeley(?) nor any sudden change in the Foraminifera and the division between these zones is based largely upon the last appearance of Lincoln species. A similar situation exists in Oregon where, according to Kleinpell (1938, p. 163), the division between the typical Nye and Astoria is not well defined. This suggests that the upper part of the Willapa Valley Astoria is a continuation of the lower Saucesian.

Kleinpell (1938, p. 116) stated that the *Siphogenerina transversa* and *Plectofrondicularia miocenica* zones represent the lower portion of the Saucesian stage. *Bulimina alligata, Nonion costiferum, Nonionella miocenica* and *Uvigerinella californica ornata* are believed to make their first appearance in these zones and these species are all present in the Willapa Valley Astoria. *Siphogenerina transversa, Uvigerinella obesa impolita, Bolivina floridana* and *Cassidulina pulchella,* which are common in the upper Saucesian (*Uvigerinella obesa* zone), are present in the upper part of the Willapa Valley section, and *Bolivina floridana* and *Cassidulina pulchella* have been regarded as first appearing in the *Uvigerinella obesa* zone. The presence of both upper and lower Saucesian species

suggests that much of the Saucesian may be represented by the Willapa Valley Astoria. Inasmuch as the faunas described from the Astoria of Oregon so closely resemble that of the Willapa Valley Astoria, it is possible that the type Astoria formation includes at least part of the lower Saucesian stage. Thus it is concluded that the Willapa Valley Astoria may represent parts of both the upper and lower Saucesian and therefore it probably lies near the top of the lower Miocene.

Summary.—Foraminifera of the Willapa Valley strata indicate an essentially continuous section ranging from probable upper Eocene to lower Miocene. The lower part is correlated with the Cowlitz formation of Washington. Indirect evidence suggests that the upper Tejon of California and the Coaledo formation and possibly the Helmick beds of Oregon may correlate, at least in part, with the lower portion of the Willapa Valley section.

Overlying the Cowlitz equivalent are strata which are correlated with at least part of the Keasey and Bastendorf formations of Oregon and with the Tumey formation of California. These formations are generally regarded to be lower Oligocene (lower Refugian).

Above the Keasey equivalent lie beds containing a typical Lincoln foraminiferal fauna. These strata may be, in part, equivalent to the Pittsburg Bluff, Tunnel Point and Eugene formations of Oregon and possibly the lower part of the San Lorenzo formation of California.

A transitional foraminiferal fauna, containing both Oligocene and Miocene species, occurs in sediments above the Lincoln. Limited evidence suggests that these beds may be equivalent to the Blakeley formation of Washington. The *Uvigerina gallowayi* zone appears to be represented at the base of these strata, and the uppermost beds may, in part at least, correlate with the Nye shale of Oregon. These so-called Blakeley(?) beds appear to represent the equivalent of at least parts of the Zemorrian and lower Saucesian of California.

The uppermost portion of the Willapa Valley section that has been studied underlies massive sandstone and contains a typical Astoria foraminiferal fauna. These beds are correlated with the lower part of the Washington Astoria formation. Inasmuch as this fauna contains species occurring in the upper and lower Saucesian of California, it is suggested that the type Astoria includes at least parts of both. Therefore, the uppermost portion of the Willapa Valley section probably lies near the top of the lower Miocene.

ACKNOWLEDGMENTS

The writer is indebted to Mr. Harold Billman of the Union Oil Company of California, for suggesting the area of study and offering many helpful suggestions. Dr. R. L. Lupher of the Shell Oil Company has also aided materially in the development of this report. Further acknowledgments are due Dr. A. K. Miller for generously offered editorial assistance and Drs. Carlton Condit, J. J. Runner, A. C. Tester and A. C. Trowbridge for their general advice. Credit is also due many of the writer's former students at the College of Puget Sound for their assistance in the field and in preparation of the samples for study. All photographs accompanying this report were retouched by Mr. Howard Webster.

SYSTEMATIC PALEONTOLOGY

Family AMMODISCIDAE
Genus AMMODISCUS Reuss, 1861
AMMODISCUS cf. INCERTUS (d'Orbigny)
Plate 63, figure 1

A few specimens from scattered localities in the Willapa Valley are similar to *A. incertus* (d'Orbigny). An *Ammodiscus* questionably referred to this species from the lower Miocene of California (Cushman and Laiming, 1931, p. 93, pl. 9, fig. 4) appears to be especially similar. Lack of sufficient recognizable material makes only tentative identification possible.

Occurrence.—Middle part of the Willapa Valley section (Keasey and Lincoln equivalents). *A. incertus* is known from a number of localities in the Caribbean region, Mexico and possibly California, ranging from Eocene to Recent.

Figured specimen.—USNM 547648.

Family LITUOLIDAE
Genus CYCLAMMINA Brady, 1876
CYCLAMMINA PACIFICA Beck
Plate 63, figure 18

Cyclammina pacifica BECK, 1943, Jour. Paleontology, vol. 17, p. 591, pl. 98, figs. 2, 3; DETLING, 1946, idem, vol. 20, p. 352, pl. 46, fig. 1; CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 4, p. 74, pl. 9, figs. 1, 2; RAU, 1948, Jour. Paleontology, vol. 22, p. 157, pl. 27, figs. 7, 8.

A few very large specimens are composed largely of dark colored sand grains but the sutural areas are typically light colored. This is characteristic of *C. pacifica*.

Occurrence.—Middle part of the Willapa Valley section (Lincoln equivalent), known previously from the Cowlitz formation and Porter shale of Washington and the Coaledo and Bastendorf formations of Oregon.

Figured specimen.—USNM 547649.

Family VERNEUILINIDAE
Genus GAUDRYINA d'Orbigny, 1839
GAUDRYINA ALAZANENSIS Cushman
Plate 63, figure 12

Gaudryina alazanensis CUSHMAN, 1936, Cushman Lab. Foram. Research Special Pub. 6, p. 14, pl. 2, figs. 17a, b; ——, 1937, idem, Special Pub. 7, p. 91, pl. 13, figs. 9a, b; RAU, 1948, Jour. Paleontology, vol. 22, p. 158, pl. 27, figs. 3, 4.

Most of the specimens consist only of the early triangular triserial stage, but a few possess the adult inflated biserial chambers. These are all almost certainly conspecific with specimens which have been referred to this species from the Porter shale of Washington.

Occurrence.—Middle and upper parts of the Willapa Valley section [Lincoln and Blakeley(?) equivalents], known previously from the Porter shale of Washington. The type specimens are from the lower Oligocene near Rio Tuxpam, Vera Cruz, Mexico.

Figured specimen.—USNM 547650.

Family VALVULINIDAE
Genus KARRERIELLA Cushman, 1933
KARRERIELLA WASHINGTONENSIS Rau
Plate 63, figure 3

Karreriella washingtonensis RAU, 1948, Jour. Paleontology, vol. 22, p. 158, pl. 27, figs. 5, 6.

Several arenaceous specimens have a distinctly necked aperture which protrudes from a sunken area in the face of the last chamber. This is typical of *K. washingtonensis*. The general shape of the test and arrangement of the chambers also coincide closely with the type.

Occurrence.—Middle and upper parts of the Willapa Valley section [Lincoln and Blakeley(?) equivalents], known previously from the Porter shale of Washington.

Figured specimen.—USNM 547651.

Family MILIOLIDAE
Genus QUINQUELOCULINA d'Orbigny, 1826
QUINQUELOCULINA GOODSPEEDI Hanna & Hanna
Plate 63, figures 6–8

Quinqueloculina goodspeedi HANNA & HANNA, 1924, Washington Univ. (Seattle) Pub. Geology, vol. 1, no. 4, p. 58, pl. 13, figs. 3, 4; BECK, 1943, Jour. Paleontology, vol. 17, p. 592, pl. 99, figs. 1, 2.

A few specimens agree in all details with the description and illustrations of this species. They are typically long and rounded but ovate in cross-section, with a circular, somewhat protruding aperture and a very narrow tooth extending up from the base.

Occurrence.—Lower part of the Willapa Valley section (Cowlitz equivalent), known previously from the type Cowlitz formation of southwest Washington.

Figured specimen.—USNM 547652.

QUINQUELOCULINA IMPERALIS
Hanna & Hanna
Plate 63, figure 13

Quinqueloculina imperalis HANNA & HANNA, 1924, Washington Univ. (Seattle) Pub. Geology, vol. 1, no. 4, p. 58, pl. 13, figs. 7, 8, 10; BECK, 1943, Jour. Paleontology, vol. 17, p. 592, pl. 98, figs. 9, 10; RAU, 1948, idem, vol. 22, p. 159, pl. 27, figs. 12–14; CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 4, p. 74, pl. 9, figs. 3a–c.

Numerous relatively broad specimens are somewhat varied in size and the apertural features are not constant. Such variations, however, are typical of this well known Pacific Northwest species. It has been discussed in some detail by Beck (1943, p. 592) and Rau (1948a, p. 159).

Occurrence.—Lower and middle parts of the Willapa Valley section (Cowlitz, Keasey and Lincoln equivalents). Known previously from the Porter shale, Cowlitz and Lincoln type localities of Washington, and the lower Coaledo of Oregon.

Figured specimen.—USNM 547653.

QUINQUELOCULINA WEAVERI Rau
Plate 63, figure 4

Quinqueloculina weaveri RAU, 1948, Jour. Paleontology, vol. 22, p. 159, pl. 28, figs. 1–3.

Several elongate specimens are slightly concave in cross-section. The last formed chamber is truncated, with the apertural face bent back. These are typical features.

Occurrence.—Lower and middle parts of the Willapa Valley section [Cowlitz, Keasey, Lincoln and Blakeley(?) equivalents], known previously from the Porter shale of southwest Washington.

Figured specimen.—USNM 547654.

QUINQUELOCULINA sp.
Plate 63, figures 10, 11

Test elongate, somewhat pointed at both ends, apertural face bent back; chambers only slightly inflated; sutures indistinct, very slightly depressed, those between last two chambers terminate at a pointed end opposite aperture; walls smooth, shiny; aperture rounded, no apparent dentition. Minimum and maximum length, 0.63–0.83 mm.; breadth, 0.49–0.55 mm.; thickness, 0.36–0.40 mm.

A few specimens differ from *Q. imperalis* by being distinctly pointed at both ends and relatively longer. The general shape is similar to *Q. akneriana* d'Orbigny but the sutures between the last two chambers differ as they terminate at the somewhat pointed end opposite the aperture. *Q. confusa* Reuss is superficially similar but differs in much the same way as *Q. akneriana* and is somewhat more compressed. These specimens seem to be distinct from any previously described form but the available material is not sufficient for the establishment of a new species.

Occurrence.—Restricted to the upper part of Willapa Valley section (Astoria equivalent).

Figured specimen.—USNM 547655.

Genus SPIROLOCULINA d'Orbigny, 1826
SPIROLOCULINA TEXANA
Cushman & Ellisor
Plate 63, figure 5

Spiroloculina texana CUSHMAN & ELLISOR, 1944, Cushman Lab. Foram. Research Contr., vol. 20, pt. 2, p. 51, pl. 8, figs. 14, 15; CUSHMAN & TODD, 1944, idem, Special Pub. 11, p. 18, pl. 3, figs. 16a, b; RAU, 1948, Jour. Paleontology, vol. 22, p. 160, pl. 28, figs. 4, 5.

Spiroloculina aff. *depressa* NUTTALL, 1932, Jour. Paleontology, vol. 6, p. 8, pl. 1, fig. 3.

A few individuals are essentially identical with specimens referred to *S. texana* Cushman & Ellisor from the Porter shale of Washington, but they differ slightly from the type, as do the Porter specimens, as the aperture is elliptical rather than round and is without any apparent dentition. More specimens may prove them to be consistently distinct.

Occurrence.—Middle part of Willapa Valley section [Lincoln and Blakeley(?) equivalents], known previously from the Porter shale of Washington. The type was described from the middle Oligocene of Brazoria County, Texas.

Figured specimen.—USNM 547656.

Genus SIGMOILINA Schlumberger, 1887
SIGMOILINA TENUIS (Czjzek)
Plate 63, figure 2

Sigmoilina tenuis CUSHMAN, 1946, Cushman Lab. Foram. Research Contr., vol. 22, pt. 2, p. 32, pl. 5, figs. 13–15.

A few specimens from the lower part of the upper section are distinctly necked but are comparable in all other respects with the description and illustrations of this species. See Cushman's (1946) discussion of this species. Since he listed the synonymy it is not repeated here.

Occurrence.—Upper part of Willapa Valley section [Blakeley(?) equivalent]. Known previously from the Vaqueros formation of California and numerous other Tertiary localities in many parts of the world. This species is also recorded from Recent sediments of the Pacific.

Figured specimen.—USNM 547657.

Genus PYRGO Defrance, 1924
PYRGO LUPHERI Rau
Plate 63, figure 9

Pyrgo lupheri RAU, 1948, Jour. Paleontology vol. 22, p. 160, pl. 28, figs. 8, 9.

Specimens are somewhat varied in shape and a few are more slender than the type as shown in the illustration. Others, however, show complete gradation.

Occurrence.—Middle and upper parts of Willapa Valley sections [Lincoln and Blakeley(?) equivalents], known previously from the Porter shale of Washington.

Figured specimen.—USNM 547658.

Family LAGENIDAE
Genus ROBULUS Montfort, 1808
ROBULUS BECKI Rau, n. sp.
Plate 63, figures 19, 20

Robulus sp. a BECK, 1943, Jour. Paleontology, vol. 17, p. 596, pl. 101, figs. 9, 10.

Test large, somewhat lobate in later development, thick, tapering rapidly to a well developed keel which is occasionally double below apertural face, completely involute; chambers distinct but not inflated, four to six in last whorl; sutures distinct, slightly limbate, flush with the surface, highly curved, especially in umbonal region; walls smooth; aperture radiate with an elongate slit below on a concave triangular apertural face, previous apertures frequently visible. Minimum and maximum length, 1.23–1.35 mm.; breadth, 1.03–1.12 mm.; thickness, 0.63–0.68 mm.

A single specimen described and illustrated by Beck from the Cowlitz formation seems essentially identical with numerous specimens from the lower portion of the Willapa Valley section. The lobate test together with highly curved sutures, especially near and in the umbonal region, typify this species. The double keel may not be an essential characteristic.

Occurrence.—Lower part of Willapa Valley section (Cowlitz, Keasey, and Lincoln equivalents), known previously from the Cowlitz formation of southwest Washington (Lewis County).

Holotype.—USNM 547659.

ROBULUS cf. CALCAR (Linné)
Plate 63, figures 23, 24

Robulus calcar CUSHMAN, 1929, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 84 pl. 12, fig. 18.

Robulus cf. *calcar* KLEINPELL, 1938, Miocene Stratigraphy of California, p. 197, pl. 3, fig. 6; CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 1, p. 13, pl. 1, figs. 3a, b.

This species is quite different from any other in the collection in that it displays a spined periphery together with raised sutures. The number of chambers in the last whorl greatly increases with the size of the test. The illustrated specimen may represent an advanced growth stage or perhaps the microspheric form of *R. calcar* (Linné). Some of the unfigured specimens seem essentially identical to those previously illustrated, especially that of Kleinpell.

Occurrence.—Upper part of Willapa Valley section [Blakeley(?) equivalent]. *R. calcar* is known from Ecuador, Venezuela and Trinidad. It is also doubtfully recorded from the Zemorrian (lowest Miocene) of California and the Astoria formation of Oregon.

Figured specimen.—USNM 547660.

ROBULUS CHEHALISENSIS Rau
Plate 64, figure 25

Robulus chehalisensis RAU, 1948, Jour. Paleontology, vol. 22, p. 162, pl. 29, figs. 14, 15.

This extremely large species is rare in the Willapa Valley material. The number of chambers in the last whorl varies considerably in different individuals, from seven to 11 in specimens from the same sample. It is easily recognized by its large size and compressed form.

Occurrence.—Lower part of Willapa Valley section (Keasey equivalent), previously known from the Porter shale of Washington.

Figured specimen.—USNM 547661.

ROBULUS HOLCOMBENSIS Rau, n. sp.
Plate 63, figures 14–17

Cristellaria rotulata HANNA & HANNA (not Lamarck), 1924, Washington Univ. (Seattle) Pub. Geology, vol. 1, no. 4, p. 61, pl. 13, figs. 14, 19, 20.

Robulus inornatus CUSHMAN & SCHENCK (not d'Orbigny), 1928, Univ. Calif. Pub. Geology, vol. 17, p. 307, pl. 42, figs. 3a, b; BECK, 1943, Jour. Paleontology, vol. 17, p. 595, pl. 104, figs. 1–4, 10, 14; DETLING, 1946, idem, vol. 20, p. 353, pl. 47, figs. 4, 5; CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 3, p. 60, pl. 7, figs. 3a, b; pt. 4, p. 74, pl. 11, figs. 6a, b; pt. 5, p. 97, pl. 13, figs. 2a, b.

Test slightly longer than broad, thick, nearly flat in the umbonal region, tapering rapidly to a thin, very narrow keel; chambers distinct, only very slightly inflated, five to seven in last whorl; sutures distinct, practically flush with the surface, somewhat limbate, curved considerably; walls smooth, shiny; aperture radiate, slightly produced, with a narrow slit below in aperture face, aperture of previous chambers frequently visible. Minimum and maximum length, 0.71–1.02 mm.; breadth, 0.61–0.90 mm.; thickness, 0.40–0.59 mm.

Several specimens from the lower part of the section show a striking resemblance to those described and illustrated as *Robulus inornatus* (d'Orbigny) from the Coaledo and Bastendorf formations of Oregon and the Cowlitz formation of Washington. In the writer's opinion, these specimens, thus far restricted to the Pacific Northwest, are sufficiently different to warrant the establishment of a new species. The present specimens are thicker than typical *R. inornatus*. They are also flatter in the umbonal region, and do not have a distinct central disc.

Occurrence.—Lower part of the Willapa Valley section (Cowlitz and Keasey equivalents). Forms seemingly conspecific are known from the Cowlitz formation of Lewis County, Washington, and the Coaledo, Helmick and Bastendorf formations of Oregon.

Syntypes.—USNM 547662.

ROBULUS NIKOBARENSIS (Schwager)
Plate 64, figures 4, 5

Cristellaria nikobarensis SCHWAGER, 1866, Novara-Exped., Geol. Theil, Bd. 2, Abt. 2, p. 243, pl. 6, fig. 87.

Robulus nikobarensis CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 1, p. 13, pl. 1, figs. 2a, b.

A rather common species from the upper part of the section compares closely with illustrations and descriptions of *R. nikobarensis* (Schwager). Those figured by Cushman, Stewart and Stewart from the Astoria formation of Oregon are especially similar to the present specimens.

Cushman, Stewart and Stewart (1947, p. 13) list the synonymy of this form which is not repeated here.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents], originally described from the Pliocene of Kar Nicobar. This species is recorded from the Pliocene of California, the Miocene of California, Oregon and Java, and the Tertiary of Japan.

Figured specimen.—USNM 547663.

ROBULUS TEXANUS (Cushman & Applin)
Plate 64, figure 18

Cristellaria articulata texana CUSHMAN & APPLIN, 1926, Am. Assoc. Petroleum Geologists Bull., vol. 10, p. 170, pl. 8, figs. 1, 2.

Robulus articulatus texanus ELLISOR, 1933, Am. Assoc. Petroleum Geologists Bull., vol. 17, p. 1336, pl. 2, fig. 3; CUSHMAN & DUSENBURY, 1934, Cushman Lab. Foram. Research

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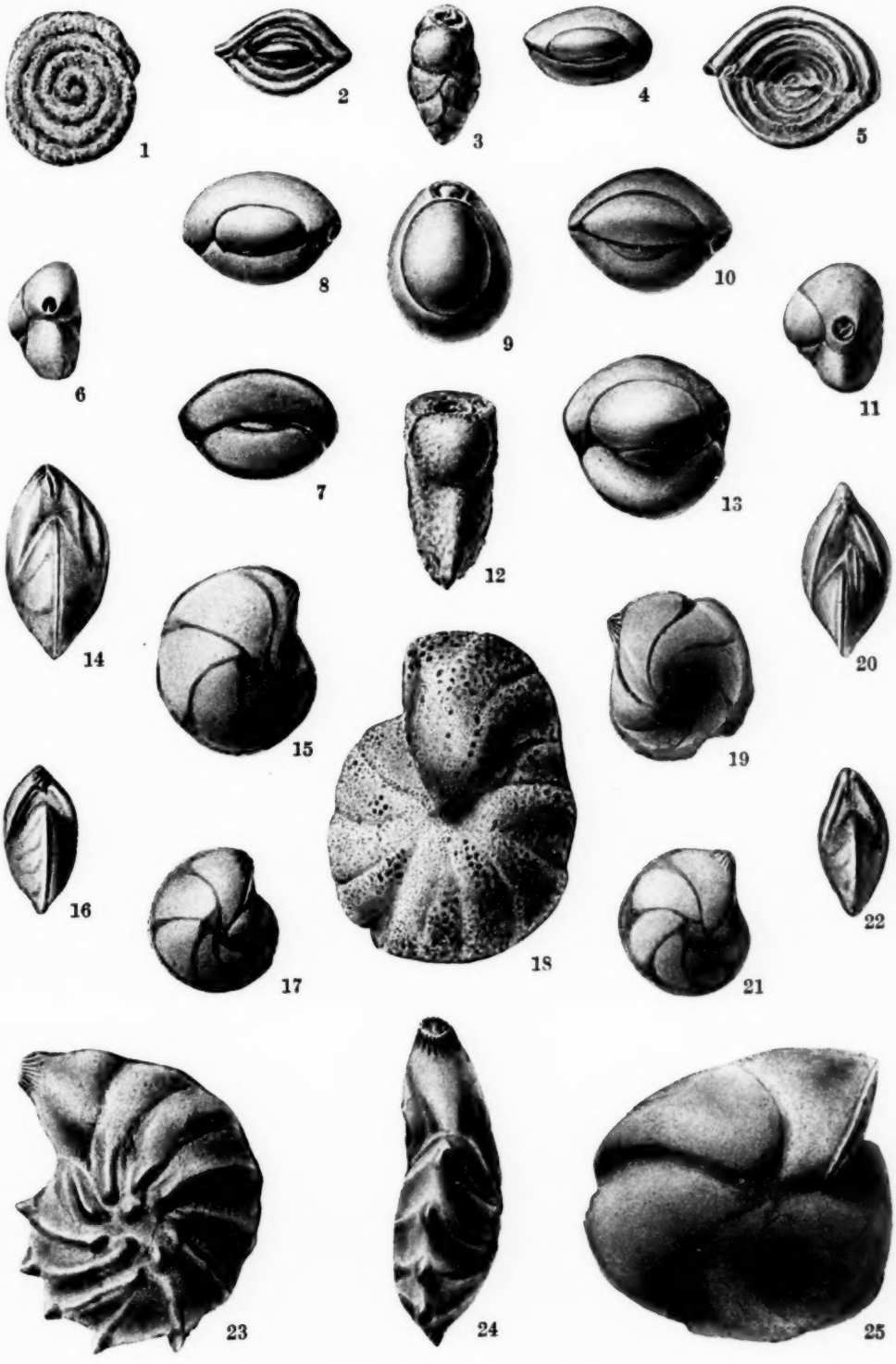
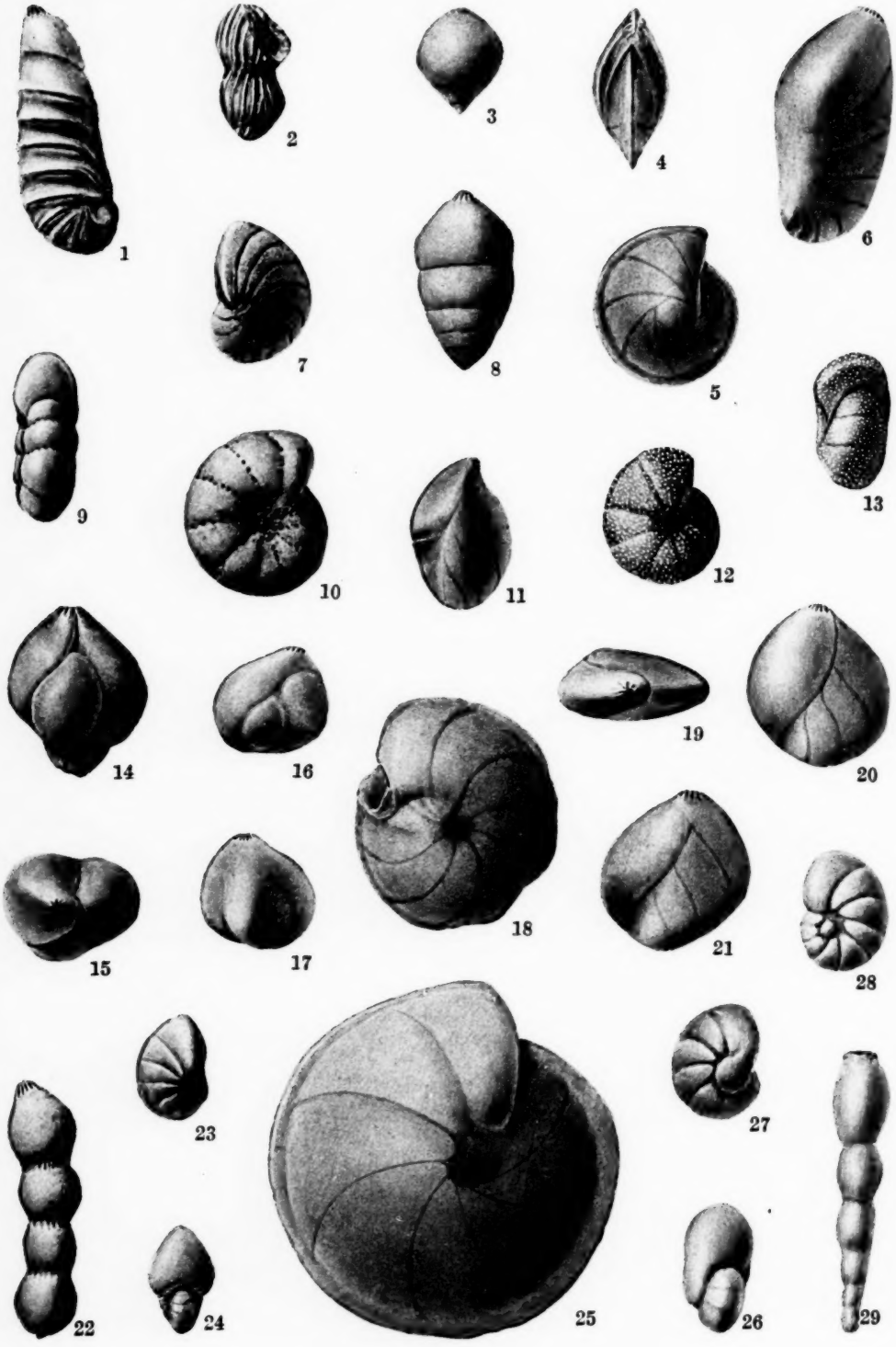
EXPLANATION OF PLATE 63

All specimens from Tertiary strata, Willapa River Valley, Pacific County, southwest Washington. Figures *2, 23, 24* from the Miocene-Oligocene Blakeley(?) equivalent; *6, 7, 8, 19, 20,* Eocene Cowlitz equivalent; *13, 14, 15, 16, 25,* Oligocene Keasey equivalent; all others Oligocene Lincoln equivalent.

FIGS. *1*—*Ammodiscus* cf. *incertus* (d'Orbigny). ×20. (p. 428)
2—*Sigmoilina tenuis* (Czjzek). ×40. (p. 430)
3—*Karreriella washingtonensis* Rau. ×20 (p. 429)
4—*Quinqueloculina weaveri* Rau. ×40. (p. 430)
5—*Spiroloculina texana* Cushman & Ellisor. ×40. (p. 430)
6–8—*Quinqueloculina goodspeedi* Hanna & Hanna. ×40. (p. 429)
9—*Pyrgo lupheri* Rau. ×40. (p. 430)
10, 11—*Quinqueloculina* sp. ×40. (p. 430)
12—*Gaudryina alazanensis* Cushman. ×40. (p. 429)
13—*Quinqueloculina imperalis* Hanna & Hanna. ×20. (p. 429)
14–17—*Robulus holcombensis* Rau, n. sp. Two syntypes. ×40. (p. 431)
18—*Cyclammina pacifica* Beck. ×20. (p. 429)
19, 20—*Robulus becki* Rau, n. sp. Holotype, ×20. (p. 431)
21, 22—*Robulus* cf. *weaveri* Beck. ×40. (p. 433)
23, 24—*Robulus* cf. *calcar* (Linné). ×20. (p. 431)
25—*Robulus?* sp. ×20. (p. 433)



Rau, Washington Tertiary Foraminifera



Rau, Washington Tertiary Foraminifera

Contr., vol. 10, pt. 3, p. 53, pl. 7, figs. 2, 3; CUSHMAN, 1935, U. S. Geol. Survey Prof. Paper 181, p. 16, pl. 4, figs. 16, 17; —— & FRIZZELL, 1943, Cushman Lab. Foram. Research Contr., vol. 19, pt. 4, p. 83, pl. 14, fig. 10; —— & SIMONSON, 1944, Jour. Paleontology, vol. 18, p. 194, pl. 30, fig. 7; ——, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 4, p. 75, pl. 9, figs. 8a, b.

Robulus texanus BECK, 1943, Jour. Paleontology, vol. 17, p. 595, pl. 103, figs. 1, 2, 4, 5; RAU, 1948, idem, vol. 22, p. 163, pl. 29, figs. 16, 17.

A few incomplete specimens have distinctly raised adult chambers, a feature characteristic of *R. texanus*.

Occurrence.—Lower part of Willapa Valley section (Cowlitz and Keasey equivalents), known previously from the Porter shale, Lincoln and Cowlitz type localities of Washington, and the lower part of the Coaledo formation of Oregon. This species is also recorded from the Poway conglomerate and the Tumey formation of California. Various other records are from the Jackson formation of the Gulf Coastal Plain, chiefly from Texas and South Carolina.

Figured specimen.—USNM 547664.

ROBULUS cf. WEAVERI Beck
Plate 63, figures 21, 22

? *Robulus weaveri* BECK, 1943, Jour. Paleontology, vol. 17, p. 595, pl. 103, figs. 3, 8.

Robulus weaveri RAU, 1948, Jour. Paleontology, vol. 22, p. 162, pl. 28, figs. 18, 19.

A few specimens in the collection compare closely with those referred to *R. weaveri* Beck from the Porter shale, but there is some question of their relationship with the types from the Cowlitz formation. The present specimens are noticeably longer than broad, and the apertural face is rarely asymmetric. They are similar to the types, however, in the tangential approach of limbate sutures to a clear umbo and the number of chambers. Actual comparison with type material is necessary before definite identification can be made.

Occurrence.—Middle part of the Willapa Valley section (Lincoln equivalent). *R. weaveri* was originally described from the type Cowlitz of southwest Washington. It is also recorded from the Porter shale of Washington.

Figured specimen.—USNM 547665.

ROBULUS? sp.
Plate 63, figure 25

? *Darbyella?* sp. RAU, 1948, Jour. Paleontology, vol. 22, p. 163, pl. 29, figs. 18, 19.

A few very large but considerably distorted specimens seem similar to those referred to as *Darybella*? sp. from the Porter shale of Washington. They are the only Foraminifera recovered from the agglomerate bed at the base of what is believed to be the Keasey equivalent in the Willapa Valley

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EXPLANATION OF PLATE 64

All specimens from Tertiary strata, Willapa River Valley, Pacific County, southwest Washington. Figures *1, 6, 8* from the Eocene Cowlitz equivalent; *2, 14, 15, 18, 19, 20, 21, 25*, Oligocene Keasey equivalent; *3, 9, 10, 29*, Oligocene-Miocene Blakeley(?) equivalent; *4, 5, 7, 26–28*, Miocene Astoria equivalent; all others Oligocene Lincoln equivalent.

FIGS. *1*—*Vaginulinopsis saundersi* (Hanna & Hanna). ×20. (p. 434)
2—*Dentalina? dusenburyi* Beck. ×20. (p. 434)
3—*Pseudoglandulina inflata* (Bornemann). ×20. (p. 434)
4, 5—*Robulus nikobarensis* (Schwager). ×20. (p. 432)
6—*Saracenaria hantkeni* Cushman. ×40. (p. 435)
7—*Nonion costiferum* (Cushman). ×40. (p. 436)
8—*Pseudoglandulina nallpeensis* Rau, n. sp. Holotype. ×40. (p. 435)
9, 10—*Elphidium minutum* Cushman. ×40. (p. 437)
11—*Sigmomorphina pseudoschencki* Rau, n. sp. Holotype. ×20. (p. 436)
12, 13—*Nonion?* cf. *planatum* Cushman & Thomas. ×40. (p. 437)
14, 15—*Guttulina frankei* Cushman & Ozawa. ×40. (p. 435)
16, 17—*Guttulina irregularis* (d'Orbigny). ×40. (p. 435)
18—*Robulus texanus* (Cushman & Applin). ×20. (p. 432)
19–21—*Sigmomorphina schencki* Cushman & Ozawa. ×20. (p. 436)
22—*Nodosaria grandis* Reuss. ×20. (p. 434)
23, 24—*Nonion* sp. ×40. (p. 437)
25—*Robulus chehalisensis* Rau. ×20. (p. 431)
26–28—*Nonionella miocenica* Cushman. ×40. (p. 437)
29—*Dentalina?* sp. ×20. (p. 434)

section. Most of these specimens have a decidedly asymmetric apertural face, but this feature appears to be the result of distortion. Until better material is obtained, it is not possible to identify them precisely.

Occurrence.—Lower part of the Willapa Valley section (Cowlitz and Keasey equivalents).

Figured specimen.—USNM 547666.

Genus VAGINULINOPSIS Silvestri, 1904

VAGINULINOPSIS SAUNDERSI (Hanna & Hanna)

Plate 64, figure 1

Cristellaria saundersi HANNA & HANNA, 1924, Washington Univ. (Seattle) Pub. Geology, vol. 1, no. 4, p. 61, pl. 13, figs. 5, 6, 15.

Vaginulina elegans mexicana NUTTALL, 1932, Jour. Paleontology, vol. 6, p. 16, pl. 3, figs. 12, 16; PALMER & BERMUDEZ, 1936, Soc. cubana hist. nat. Mem., vol. 10, p. 277, pl. 14, figs. 23, 24.

Vaginulinopsis saundersi BECK, 1943, Jour. Paleontology, vol. 17, p. 598, pl. 105, figs. 1, 2, 4, 5, 10; RAU, 1948, idem, vol. 22, p. 164, pl. 30, figs. 19–22.

Specimens occur in the lower part of the section that are almost certainly referable to this species which, until recently, was believed to be restricted to the Eocene Cowlitz formation or its probable equivalent. Current studies, however, have also revealed its occurrence in thin stratigraphic zones in several parts of the Northwest Oligocene. This suggests that *V. saundersi* has a rather wide stratigraphic range but required specific environmental conditions for existence.

Occurrence.—Lower part of the Willapa Valley section (Cowlitz equivalent), known previously from the Porter shale and type Cowlitz of southwest Washington, the Alazan shale of Mexico, and the Tertiary of Cuba. It is now also known from several Oligocene zones in Washington.

Figured specimen.—USNM 547667.

Genus DENTALINA d'Orbigny, 1826

DENTALINA? DUSENBURYI Beck

Plate 64, figure 2

? *Dentalina dusenburyi* BECK, 1943, Jour. Paleontology, vol. 17, p. 599, pl. 105, figs. 20, 23; RAU, 1948, idem, vol. 22, p. 167, pl. 30, fig. 24; CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 4, p. 76, pl. 10, figs. 1–3.

A few fragmentary specimens compare favorably with the description and illustrations of this species but definite identification is impossible. The chambers are large and ornamented with longitudinal costae.

Occurrence.—Lower part of Willapa Valley section (Keasey equivalent). This species is known from the Cowlitz formation and Porter shale of Washington. It is also recorded from the lower Coaledo of Oregon.

Figured specimen.—USNM 547668.

DENTALINA? sp.

Plate 64, figure 29

There are a few incomplete, slightly arcuate specimens in the collection. These vary considerably in size, and their chambers are not uniformly shaped. It is impossible to identify them accurately.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) equivalent].

Figured specimen.—USNM 547669.

Genus NODOSARIA Lamarck, 1812

NODOSARIA GRANDIS Reuss

Plate 64, figure 22

Nodosaris grandis REUSS, 1866, K. Akad. Wiss. Wien, Math.-Naturwiss. Cl. Denkschr., Bd. 25, Abt. 1, p. 131, pl. 1, figs. 26–28; RAU, 1948, Jour. Paleontology, vol. 22, p. 167, pl. 30, fig. 9.

Some specimens vary slightly from the figured types and those of the Porter shale in that they are somewhat arcuate, but the sutures are not oblique. Perhaps they should be referred to *Dentalina*.

Occurrence.—Middle part of the Willapa Valley section [Keasey, Lincoln and Blakeley(?) equivalents], known previously from the Porter shale of Washington and several Tertiary localities in Europe.

Figured specimen.—USNM 547670.

Genus PSEUDOGLANDULINA Cushman, 1929

PSEUDOGLANDULINA INFLATA (Bornemann)

Plate 64, figure 3

Glandulina inflata BORNEMANN, 1855, Deutsche geol. Gesell. Zeitschr., Bd. 7, Heft 2, p. 320, pl. 12, figs. 6, 7.

Pseudoglandulina inflata CUSHMAN & FRIZZELL, 1943, Cushman Lab. Foram. Research Contr., vol. 19, pt. 4, p. 84, pl. 14, fig. 14; RAU, 1948, Jour. Paleontology, vol. 22, p. 168, pl. 30, fig. 3.

Individuals of this species vary somewhat. A few are more slender than the figured type but others are essentially similar.

Occurrence.—Middle part of the Willapa Valley section [Lincoln and Blakeley(?) equivalents], known previously from the Lincoln formation (type locality) and the Porter shale of Washington. This species was originally described from the Oligocene of Europe.

Figured specimen.—USNM 547671.

PSEUDOGLANDULINA NALLPEENSIS
Rau, n. sp.
Plate 64, figure 8

Test somewhat elongate, greatest diameter near center of last formed chamber, tapering rapidly toward apertural end, tapering gently at first and then more rapidly toward pointed initial end; chambers distinct, especially last one or two, uniserially throughout, five to six chambers visible; sutures fairly distinct, slightly depressed between last two or three chambers, the remainder flush with the surface; walls smooth, shiny; aperture radiate, strongly produced and centrally located. Minimum and maximum length, 0.48–0.72 mm.; diameter, 0.37–0.39 mm.

Specimens are not common in the collection but they are well preserved and seem to be distinct from any previously described species. They are similar to a form from the Llajas formation of California which was figured as *Pseudoglandulina* (?) sp. by Cushman and McMasters (1936, p. 512, pl. 75, figs. 13a, b, 14a, b) but the latter differs by being smaller and having fewer visible chambers. Cushman and Simonson (1944, p. 196, pl. 31, fig. 13) have illustrated a specimen from the Tumey formation of California which is also similar but differs in having a considerably smaller apertural angle and probably also fewer chambers.

Occurrence.—Lower part of the Willapa Valley section (Cowlitz equivalent).

Holotype.—USNM 547672.

Genus SARACENARIA Defrance, 1824
SARACENARIA HANTKENI Cushman
Plate 64, figure 6

Saracenaria arcuata hantkeni CUSHMAN, 1933, Cushman Lab. Foram. Research Contr., vol. 9, pt. 1, p. 4, pl. 1, figs. 11, 12; ——, 1935, U. S. Geol. Survey Prof. Paper 181, p. 17, pl. 5, figs. 6, 7.

Saracenaria hantkeni BECK, 1943, Jour. Paleontology, vol. 17, p. 600, pl. 106, figs. 9, 12; CUSHMAN, 1946, Cushman Lab. Foram. Research Special Pub. 16, p. 14, pl. 3, fig. 21; DETLING, 1946, Jour. Paleontology, vol. 20, p. 354, pl. 48, figs. 9a, b.

A few specimens compare closely with illustrations of typical *S. hantkeni* Cushman. Those previously figured from the Pacific Northwest are especially similar and differ from the Willapa specimens only in having sutures that are possibly more depressed.

Occurrence.—Lower part of Willapa Valley section (Cowlitz equivalent), known previously from the type Cowlitz of southwest Washington (Lewis County), the Coaledo formation of Oregon and the Cocoa sand member of the Jackson formation of Alabama. This species was originally described from the Cooper marl of South Carolina.

Figured specimen.—USNM 547673.

Family POLYMORPHINIDAE
Genus GUTTULINA d'Orbigny, 1839
GUTTULINA IRREGULARIS (d'Orbigny)
Plate 64, figures 16, 17

Guttulina irregularis CUSHMAN & OZAWA, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, pp. 25–27, pl. 7, figs. 1, 2; CUSHMAN & THOMAS, 1929, Jour. Paleontology, vol. 3, p. 177, pl. 23, figs. 2a–c; RAU, 1948, idem, vol. 22, p. 169, pl. 30, figs. 7, 8.

The specimens vary considerably but all possess the general characteristics of this species. *G. byramensis* (Cushman) of the Bastendorf of Oregon, referred to by several writers, may also be conspecific.

Occurrence.—Lower and middle parts of the Willapa Valley section (Cowlitz, Keasey and Lincoln equivalents), recorded previously from the type Cowlitz and Porter shale of Washington and the Zemorrian of California. Known also from many other localities throughout the world, ranging stratigraphically from Cretaceous to Recent.

Figured specimen.—USNM 547674.

GUTTULINA FRANKEI Cushman & Ozawa
Plate 64, figures 14, 15

Guttulina frankei CUSHMAN & OZAWA, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 28, pl. 4, fig.

1; CUSHMAN & FRIZZELL, 1943, Cushman Lab. Foram. Research Contr., vol. 19, pt. 4, p. 84, figs. 17, 18; RAU, 1948, Jour. Paleontology, vol. 22, p. 170, pl. 30, figs. 17, 18.

The chambers of some specimens are more inflated than those figured by Cushman and Ozawa, but others are gradational to the typical form. Similar variation occurs among specimens from the Porter shale of Washington.

Occurrence.—Middle part of the Willapa Valley section [Keasey, Lincoln and Blakeley(?) equivalents], known previously from the Porter shale and type Lincoln of Washington. The original specimens are from the Oligocene of Germany.

Figured specimen.—USNM 547675.

Genus SIGMOMORPHINA Cushman & Ozawa, 1928

SIGMOMORPHINA PSEUDOSCHENCKI Rau, n. sp.

Plate 64, figure 11

Sigmomorphina schencki RAU (not Cushman & Ozawa), 1948, Jour. Paleontology, vol. 22, p. 170, pl. 30, figs. 13, 14.

Test compressed, ovate, broadly rounded at base and somewhat acute at apertural end with greatest breadth near middle; chambers elongate, not inflated, embracing, arranged in a sigmoid clockwise series, each succeeding chamber increasingly removed from the base; sutures indistinct, flush with the surface; walls smooth, shiny; aperture radiate and somewhat produced. Minimum and maximum length, 1.03–1.07 mm.; breadth, 0.69–0.72 mm.; thickness, 0.40–0.42 mm.

This form was first encountered in the Porter shale of Washington and was identified as *S. schencki* Cushman & Ozawa, which has many similar characteristics. The present collection contains both species which occur in different zones. *S. schencki* is present in the lower part of the Willapa Valley Keasey, whereas the other marks the middle and upper Lincoln and the lower Blakeley(?) equivalents. The present species differs from *S. schencki* in that it is not as broad, is more acute at the apertural end, and the aperture is noticeably produced. *S. undulata* Rau, also from the Porter shale, approaches this species but differs in being somewhat quadrangular in shape and having slightly inflated chambers and a distinctly undulating periphery.

Occurrence.—Middle part of the Willapa Valley section [Lincoln and Blakeley(?) equivalents], also known from the Porter shale of Washington.

Holotype.—USNM 547676.

SIGMOMORPHINA SCHENCKI Cushman & Ozawa

Plate 64, figures 19–21

? *Sigmoidella elegantissima* CUSHMAN & SCHENCK, 1928, California Univ., Dept. Geol. Sci. Bull., vol. 17, no. 9, p. 310, pl. 43, figs. 12, 13.

Sigmomorphina schencki CUSHMAN & OZAWA, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 133, pl. 35, figs. 6a, b.

A few broadly ovate specimens from the lower part of the section correspond in practically every detail to the published description and illustrations of this species from the Keasey shale of Oregon. A form referred to as *Sigmoidella elegantissima* (Parker & Jones) by Cushman and Schenck from the Keasey shale also appears very similar.

Occurrence.—Lower part of Willapa Valley section (Keasey equivalent), known previously from the Keasey shale of Oregon.

Figured specimen.—USNM 547677.

Family NONIONIDAE

Genus NONION Montfort, 1808

NONION COSTIFERUM (Cushman)

Plate 64, figure 7

Nonionella boueana CHAPMAN (not d'Orbigny), 1900, California Acad. Sci. Proc., ser. 3, Geol., vol. 1, p. 225, pl. 30, figs. 14, 14a.

Nonionella costifera CUSHMAN, 1926, Cushman Lab. Foram. Research Contr., vol. 1, pt. 4, p. 90, pl. 13, figs. 2a–c.

Nonion costifera CUSHMAN, STEWART & STEWART, 1930, San Diego Soc. Nat. History Trans., vol. 6, no. 2, p. 60, pl. 3, fig. 13.

Nonion costiferum CUSHMAN & PARKER, 1931, Cushman Lab. Foram. Research Contr., vol. 7, pt. 1, p. 7, pl. 1, figs. 27a, b; CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries, Bull. 36, pt. 2, p. 44, pl. 5, figs. 5a, b; RAU, 1948, Jour. Paleontology, vol. 22, p. 777, pl. 119, figs. 5, 6.

Numerous specimens occur in many samples from the upper part of the section which compare closely with the description and illustrations of this species. Comparison

of actual specimens from the Miocene of Washington indicates that the Willapa Valley specimens are unquestionably conspecific. Rau (1948b) listed the synonymy which is not repeated here.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents], known previously from numerous areas of the California Miocene as well as several Miocene localities in Oregon and Washington. (See Kleinpell, 1938, pp. 229–231, for some specific localities.)

Figured specimen.—USNM 547678.

NONION? cf. PLANATUM
Cushman & Thomas
Plate 64, figures 12, 13

? *Nonion planatum* CUSHMAN & THOMAS, 1930, Jour. Paleontology, vol. 4, p. 37, pl. 3, figs. 5a, b; CUSHMAN & DUSENBURY, 1934, Cushman Lab. Foram. Research Contr., vol. 10, pt. 3, p. 60, pl. 8, figs. 6a, b; CUSHMAN, 1939, U. S. Geol. Survey Prof. Paper 191, p. 4, pl. 1, fig. 15; BECK, 1943, Jour. Paleontology, vol. 17, p. 603, pl. 107, figs. 12, 13; CUSHMAN, 1946, Cushman Lab. Foram. Research Special Pub. 16, p. 21, pl. 4, fig. 24; —— & TODD, 1948, idem, Contr., vol. 24, pt. 2, p. 32, pl. 6, fig. 1.

A form occurring in numerous samples from much of the section is most comparable with the description and illustrations of this species. The specimen figured by Beck seems particularly similar. The Willapa Valley individuals are, however, slightly asymmetric and some also possess a very small and indistinct plate-like structure in the umbilical region of one side, a feature typical of *Valvulineria*. Because these specimens appear to be more nearly like several illustrations of *N. planatum*, but also possess features not characteristic of the genus, the generic assignment is questioned.

Occurrence.—Lower and middle parts of the Willapa Valley section [Keasey, Lincoln and Blakeley(?) equivalents]. *N. planatum* is known from the middle and upper Eocene and lower Oligocene of the Gulf Coastal Plain of the United States and the Tejon and Kreyenhagen formations and Poway conglomerate of California. It is also known from the Bastendorf and Coaledo formations of Oregon and the type Cowlitz of Washington.

Figured specimen.—USNM 547679.

NONION sp.
Plate 64, figures 23, 24

A few very small specimens from a single sample in the Lincoln equivalent seem to be distinct from previously described species, but because of poor preservation it is impossible to be certain. Inasmuch as they were found in only one sample they may prove to be of considerable stratigraphic value. The best preserved specimen is figured.

Occurrence.—Middle part of the Willapa Valley section (Lincoln equivalent).

Figured specimen.—USNM 547680.

Genus NONIONELLA Cushman, 1926
NONIONELLA MIOCENICA Cushman
Plate 64, figures 26–28

Nonion auris CUSHMAN (not d'Orbigny), 1926, Cushman Lab. Foram. Research Contr., vol. 1, pt. 4, p. 91, pl. 13, figs. 4a–c.

Nonionella miocenica CUSHMAN, 1939, U. S. Geol. Survey Prof. Paper 191, p. 31, pl. 8, figs. 9a–c; ——, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 2, p. 44, pl. 5, fig. 6.

An occasional specimen of this species occurs in samples from the upper part of the section. Cushman, Stewart and Stewart (1947, p. 44) list the synonymy which is not repeated here.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents], known previously from the Monterey shale, Temblor formation and the Reef Ridge of California, as well as from the Astoria of Lincoln County in western Oregon. This species also is living at present off the west coast of America from Alaska to Costa Rica. See Kleinpell (1938, p. 237) for some detailed occurrences in the California Miocene where it is common.

Figured specimen.—USNM 547681.

Genus ELPHIDIUM Montfort, 1808
ELPHIDIUM MINUTUM (Reuss)
Plate 64, figures 9, 10

Polystomella minuta REUSS, 1864 (1865), K. Akad. Wiss. Wien, Math.-Naturwiss. Cl., Sitzungsber., Bd. 50, Abt. 1, p. 478, pl. 4, figs. 6a, b.

Elphidium minutum CUSHMAN, 1939, U. S. Geol. Survey Prof. Paper 191, p. 40, pl. 10, figs. 22–24.

A few specimens agree closely with

Cushman's description and illustrations. The test is compressed with a rounded periphery. The chambers are distinct and somewhat inflated with sutures slightly curved and retral processes indistinct. *E. nautiloideum* Galloway & Heminway (see Ellis and Messina, 1940–1950) is also similar, but differs in having more numerous and less inflated chambers and an aperture consisting of a series of pores at the base of the last chamber with scattered pores on the septal face, quite different from the simple, low-lying slit at the base of the septal face on the Willapa specimens.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) equivalent], known previously from the upper Oligocene of Germany.

Figured specimen.—USNM 547682.

Family HETEROHELICIDAE
Genus PLECTOFRONDICULARIA
Liebus, 1903
PLECTOFRONDICULARIA BILLMANI
Rau, n. sp.
Plate 65, figure 3

Test small, compressed, rather narrow, increasing in width gradually from a somewhat pointed initial end; chambers indistinct in early development, later distinct and extending back biserially toward initial end, forming an unusually small angle at the apertural end; sutures slightly depressed, distinctly limbate; walls smooth except for a single costa extending from initial end over the early portion of the test. Minimum and maximum length, 0.43–0.73 mm.; breadth, 0.23–0.53 mm.; thickness, 0.05–0.06 mm.

A species illustrated and described, but not named, by Barbat and von Estorff (1933, p. 170, pl. 23, fig. 5) from the lower Miocene of California appears similar to those here considered but differs in that the initial end is blunter and the test proportionately wider. Barbat and von Estorff noted that their illustrated specimen is a megalospheric form, and the Willapa Valley specimens may be microspheric forms of the same species. *P. vaughani* Cushman, although somewhat similar, should not be confused with this species, as it is much wider, with a blunt unornamented base and has an alternation of chambers not possessed by *P. billmani.*

Occurrence.—Upper part of the Willapa Valley section (Astoria equivalent). Barbat and von Estorff's specimens are from the Vaqueros formation (lower Zemorrian) of California. This species also has been recorded from the Upper Zemorrian of California.

Holotype.—USNM 547683.

PLECTOFRONDICULARIA CALIFORNICA
Cushman & Stewart
Plate 65, figure 4

Plectofrondicularia californica CUSHMAN & STEWART, 1926, Cushman Lab. Foram. Research Contr., vol. 2, pt. 2, p. 39, pl. 6, figs. 9–11; NUTTALL, 1928, Geol. Soc. London Quart. Jour., vol. 84, p. 92, pl. 6, fig. 9; GALLOWAY & MORREY, 1929, Bull. Am. Paleontology, vol. 15, no. 55, p. 36, pl. 5, fig. 11; CUSHMAN, 1929, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 90, pl. 13, figs. 18, 19; HEDBERG, 1937, Jour. Paleontology, vol. 11, p. 357, pl. 91, fig. 7; KLEINPELL, 1938, Miocene Stratigraphy of California, p. 239, pl. 4, figs. 17, 19; CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 1, p. 16, pl. 2, figs. 2a, b.

Several specimens from a single sample from the upper portion of the section are essentially identical to illustrations of the type and numerous other figures of this species. The test is long and slender with three distinct carinae at the periphery and a short costa over the early portion.

Occurrence.—Upper part of the Willapa Valley section (Astoria equivalent). Originally described and illustrated from the Pliocene of California and now known from much of the Miocene and upper Oligocene of California and Oregon. This species has also been recorded from parts of the Lower and Upper Tertiary of Ecuador and the Caribbean region.

Figured specimen.—USNM 547684.

PLECTOFRONDICULARIA PACKARDI
Cushman & Schenck
Plate 65, figure 12

Plectofrondicularia packardi CUSHMAN & SCHENCK, 1928, California Univ., Dept. Geol. Sci. Bull., vol. 17, p. 311, pl. 43, figs. 14, 15; CUSHMAN & SIMONSON, 1944, Jour. Paleontology, vol. 18, p. 197, pl. 31, figs. 17, 18, pl. 32, fig. 1; DETLING, 1946, idem, vol. 20, p. 355, pl. 49, fig. 1; CUSHMAN & STONE, 1947, Cushman Lab. Foram. Research Special Pub. 20,

p. 11, pl. 2, fig. 4; CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 5, p. 100, pl. 13, fig. 7.

This species is restricted to the lower part of the section where it usually occurs in association with *P. packardi multilineata*. (See remarks concerning that form.)

Occurrence.—Lower part of the Willapa Valley section (Cowlitz and Keasey equivalents), known previously from the Bastendorf, Coaledo and Helmick formations of Oregon and the Tumey formation and Kreyenhagen shale of California. This species has also been recorded recently from the Chira shale of Peru.

Figured specimen.—USNM 547685.

PLECTOFRONDICULARIA PACKARDI MULTILINEATA Cushman & Simonson
Plate 65, figures 1, 2

Plectofrondicularia packardi multilineata CUSHMAN & SIMONSON, 1944, Jour. Paleontology, vol. 18, p. 197, pl. 32, figs. 2–4; DETLING, 1946, idem, vol. 20, p. 355, pl. 49, figs. 3, 5; RAU, idem, vol. 22, p. 171, pl. 30, fig. 19.

This variety was found in many samples with *P. packardi* as well as in samples stratigraphically above those containing the typical form. Differentiation is often difficult and variations seem to be almost completely gradational, but asymmetry of the early portion of the test is usually more pronounced in the typical forms, whereas nearly straight and better developed costae are more frequent on the variety. The close relationship of these two forms in both structure and occurrence in the lower part of the section suggests an evolutionary development during this period of deposition.

Occurrence.—Lower and middle parts of the Willapa Valley section [Cowlitz, Keasey, Lincoln and Blakeley(?) equivalents]. Previously recorded from the Porter shale of Washington, the Coaledo and Bastendorf formations of Oregon and the Tumey formation of California.

Figured specimens.—USNM 547686.

PLECTOFRONDICULARIA VAUGHANI Cushman
Plate 65, figure 11

Plectofrondicularia vaughani CUSHMAN, 1927, Cushman Lab. Foram. Research Contr., vol. 3, pt. 2, p. 112, pl. 23, fig. 3; ——, 1929, idem, Contr., vol. 5, pt. 4, p. 92, pl. 13, figs. 21, 22; HADLEY, 1934, Bull. Am. Paleontology, vol. 20, no. 70A, p. 15, pl. 2, fig. 5; CUSHMAN & HOBSON, 1935, Cushman Lab. Foram. Research Contr., vol. 11, p. 59, pl. 9, figs. 1a, b; NUTTALL, 1935, Jour. Paleontology, vol. 9, p. 127, pl. 14, fig. 25; CORYELL & EMBICH, 1937, idem, vol. 11, p. 303, pl. 42, fig. 15; HEDBERG, 1937, idem, vol. 11, p. 675, pl. 91, fig. 17.

Plectofrondicularia cf. *vaughani* CUSHMAN, 1935, U. S. Geol. Survey Prof. Paper 181, p. 34, pl. 12, figs. 8, 9.

Specimens broad at the initial end, increasing rapidly in width toward the apertural end, and possess distinctly alternating chambers. These are characteristic features of the species.

Occurrence.—Middle part of the Willapa Valley section (Keasey and Lincoln equivalents). Known previously from the Tertiary of Mexico, Venezuela, Ecuador, Trinidad, Jamaica, Cuba and Panama, ranging stratigraphically from upper Eocene to middle Miocene. This species has also been recorded from the San Lorenzo and Vaqueros formations and Temblor shale of California.

Figured Specimen.—USNM 547687.

Family BULIMINIDAE
Genus BULIMINELLA Cushman, 1911
BULIMINELLA SUBFUSIFORMIS Cushman
Plate 65, figure 5

Buliminella subfusiformis CUSHMAN, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pt. 2, p. 33, pl. 5, fig. 12; ——, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 1, p. 17, pl. 2, figs. 7a, b.

This species occurs consistently in numerous samples from the upper portion of the section. The specimens have nearly straight sides and numerous inflated chambers, typical of the species.

Cushman, Stewart and Stewart (1947, p. 17) list the synonymy of this form which is not duplicated here.

Occurrence.—Upper part of Willapa Valley section [Blakeley(?) and Astoria equivalents], known previously from the Miocene of Florida, North Carolina, California, Sumatra and the Nye shale and Astoria formation of Oregon. See Kleinpell (1938, p. 251) for some detailed occurrences on the Pacific Coast.

Figured specimen.—USNM 547688.

Genus BULIMINA d'Orbigny, 1826

BULIMINA ALLIGATA Cushman & Laiming

Plate 65, figure 6

Bulimina inflata alligata CUSHMAN & LAIMING, 1931, Jour. Paleontology, vol. 5, p. 107, pl. 11, figs. 17a, b; KLEINPELL, 1938, Miocene Stratigraphy of California, p. 254, pl. 7, fig. 1.

Bulimina alligata CUSHMAN & PARKER, 1947, U. S. Geol. Survey Prof. Paper 210-D, p. 112, pl. 26, fig. 14; CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 1, p. 18, pl. 2, fig. 11a, b.

Specimens occur in several samples from the upper part of the section. Longitudinal costae broken at the sutures occur on the lower portion of the test, a feature typical of the species. These specimens are somewhat similar to *B. rinconensis* Cushman & Laiming but differ in that the chambers are not angular but rounded as in the type *B. alligata*.

Occurrence.—Upper part of the Willapa Valley section (Astoria equivalent), known previously from the Saucesian (lower Miocene) of California and the Astoria shale of Oregon. This species is also recorded from the Oligocene and Pliocene of California.

Figured specimen.—USNM 547689.

BULIMINA cf. OVATA d'Orbigny

Plate 65, figure 10

? *Bulimina ovata* D'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiaire de Vienne (Autriche), p. 185, pl. 11, figs. 13, 14; CUSHMAN & PARKER, 1937, Cushman Lab. Foram. Research Contr., vol. 13, pt. 2, p. 47, pl. 6, figs. 4, 5; CUSHMAN, 1946, idem, Special Pub. 16, p. 23, pl. 5, fig. 2; —— & PARKER, 1947, U. S. Geol. Survey Prof. Paper 210-D, p. 106, pl. 25, figs. 8, 9; ——, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 1, p. 18, pl. 2, fig. 1; pt. 2, p. 46, pl. 5, fig. 9.

Numerous specimens from the upper part of the section compare favorably with the type and many other figured individuals of this species, especially those of Cushman and Parker. Due to the delicate nature of these specimens almost all are crushed, making accurate identification practically impossible.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents]. *B. ovata* is known from the

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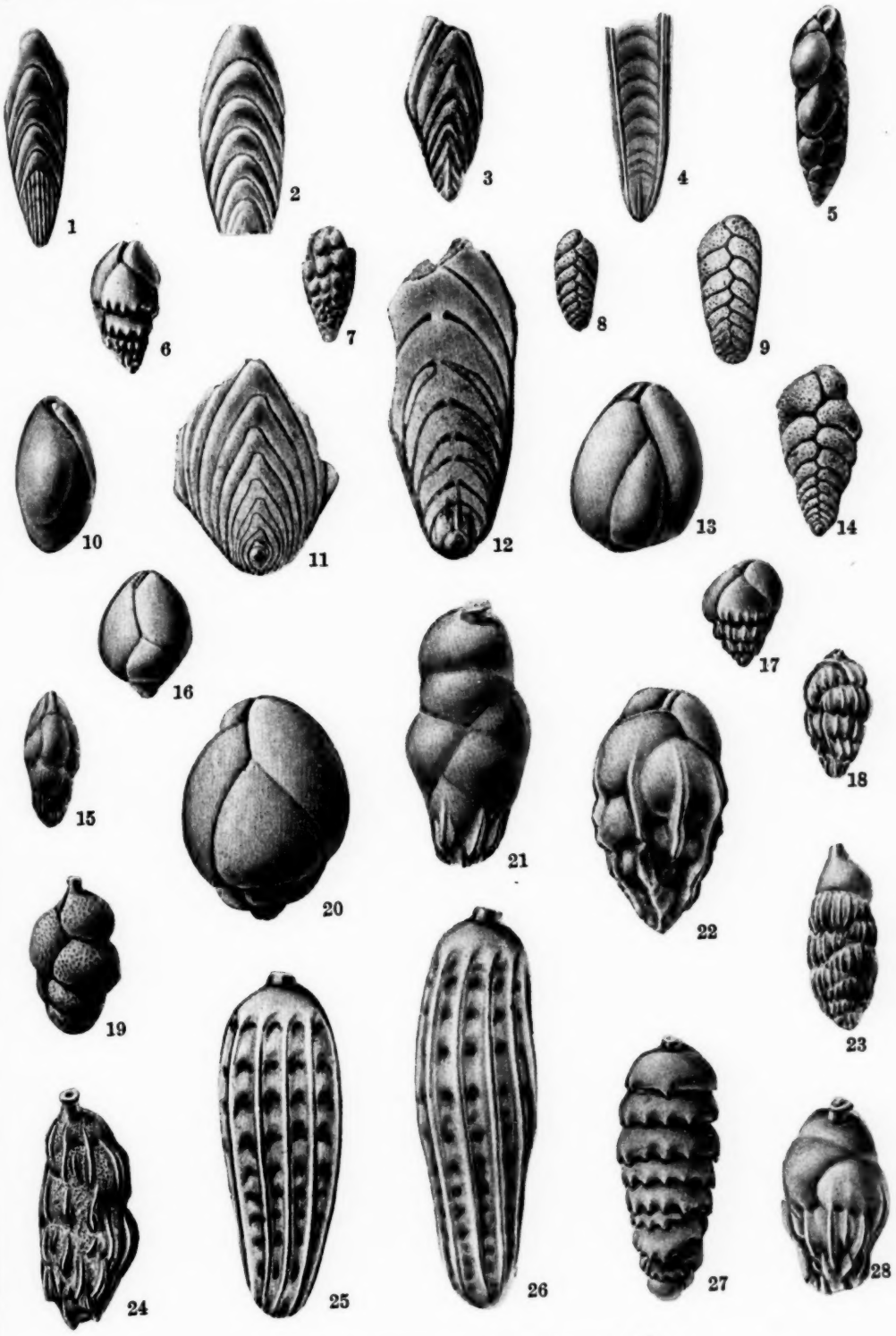
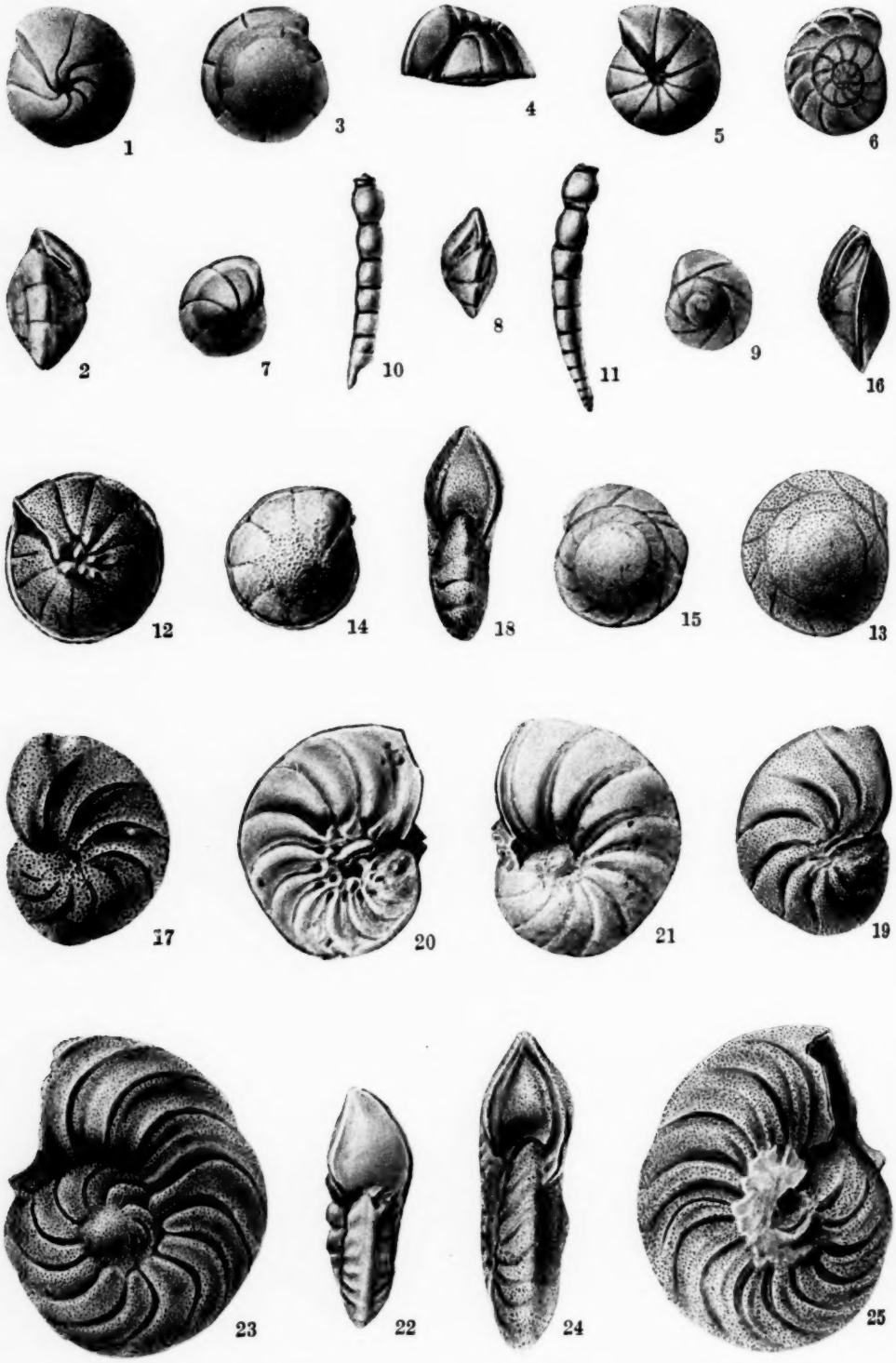
EXPLANATION OF PLATE 65

All specimens from Tertiary strata, Willapa River Valley, Pacific County, southwest Washington. Figures *1, 2, 8, 11, 13, 28* from the Oligocene Lincoln equivalent; *12, 16, 19, 20, 21, 22*, Oligocene Keasey equivalent; *17, 18, 24*, Oligocene-Miocene Blakeley(?) equivalent; all others Miocene Astoria equivalent.

FIGS. *1, 2*—*Plectofrondicularia packardi multilineata* Cushman & Simonson. ×20. (p. 439)
3—*Plectofrondicularia billmani* Rau, n. sp. Holotype, ×40. (p. 438)
4—*Plectofrondicularia californica* Cushman & Stewart. ×40. (p. 438)
5—*Buliminella subfusiformis* Cushman. ×40. (p. 439)
6—*Bulimina alligata* Cushman & Laiming. ×40. (p. 440)
7—*Bolivina floridana* Cushman. ×40. (p. 442)
8—*Bolivina* cf. *jacksonensis* Cushman & Applin. ×40. (p. 443)
9—*Bolivina advena* Cushman. ×40. (p. 442)
10—*Bulimina* cf. *ovata* d'Orbigny. ×40. (p. 440)
11—*Plectofrondicularia vaughani* Cushman. ×40. (p. 439)
12—*Plectofrondicularia packardi* Cushman & Schenck. ×40. (p. 438)
13—*Globobulimina hannai* Cushman & Ellisor. ×40. (p. 442)
14—*Bolivina marginata adelaidana* Cushman & Kleinpell. ×40. (p. 443)
15—*Uvigerinella californica ornata* Cushman. ×40. (p. 443)
16, 20—*Bulimina* cf. *pyrula* d'Orbigny. ×40. (p. 441)
17—*Bulimina* sp. ×40. (p. 442)
18—*Uvigerinella obesa impolita* Cushman & Laiming. ×40. (p. 443)
19—*Uvigerina garzaensis* Cushman & Siegfus. ×40. (p. 445)
21—*Uvigerina atwilli* Cushman & Simonson. ×40. (p. 444)
22—*Bulimina sculptilis laciniata* Cushman & Parker. ×40. (p. 441)
23—*Uvigerina* cf. *carmeloensis* Cushman & Kleinpell. ×40. (p. 444)
24—*Uvigerina gallowayi* Cushman. ×40. (p. 444)
25–27—*Siphogenerina transversa* Cushman. Three specimens; *25, 26*, with external ornamentation; *27*, internal insoluble portion. ×40. (p. 445)
28—*Uvigerina cocoaensis* Cushman. ×40. (p. 444)



Rau, Washington Tertiary Foraminifera



Rau, Washington Tertiary Foraminifera

Astoria formation of Oregon as well as from many other localities throughout the world. Apparently this species has a wide stratigraphic range as it is recorded from the Recent and much of the Tertiary. See Kleinpell (1938, p. 255) for some detailed occurrences on the Pacific Coast.

Figured specimen.—USNM 547690.

BULIMINA cf. PYRULA d'Orbigny
Plate 65, figures 16, 20

? *Bulimina pyrula* D'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiaire de Vienne (Autriche), p. 184, pl. 11, figs. 9, 10; CUSHMAN & PARKER, 1937, Cushman Lab. Foram. Research Contr., vol. 13, pt. 2, p. 46, pl. 6, figs. 1a–c; —— & ——, 1947, U. S. Geol. Survey Prof. Paper 210-D, p. 104, pl. 25, figs. 2a–c.

A few specimens from the lower part of the section vary considerably in size and shape. Their greatest thickness is usually about the center of the test or slightly below, from which they taper rapidly to a pointed initial end and more gradually to a somewhat pointed apertural end. The last three chambers make up most of the visible test. A large majority of specimens seem most similar to the typical *B. pyrula* d'Orbigny as well as individuals illustrated and described by Cushman and Parker, but none are spined like the latter.

Cushman and Parker (1947, p. 104) list the synonymy and this is not repeated.

Occurrence.—Lower and middle parts of the Willapa Valley section (Cowlitz, Keasey and Lincoln equivalents). *B. pyrula* has been recorded from Recent sediments and much of the Tertiary from numerous localities in various parts of the world. See Cushman and Parker (1947, p. 104) for general discussion.

Figured specimens.—USNM 547691.

BULIMINA SCULPTILIS LACINIATA
Cushman & Parker
Plate 65, figure 22

Bulimina sculptilis CUSHMAN & SCHENCK (not Cushman), 1928, California Univ., Dept. Geol. Sci. Bull., vol. 17, p. 311, pl. 43, fig. 16.
Bulimina sculptilis laciniata CUSHMAN & PARKER, 1937, Cushman Lab. Foram. Research Contr., vol. 13, pt. 1, p. 38, pl. 4, figs. 4a–c; —— & ——, 1947, U. S. Geol. Survey Prof. Paper 210-D, p. 103, pl. 24, fig. 13a, b.

The specimens vary considerably in size and somewhat in form but constitute an essentially gradational series. The largest are similar in all respects to the illustrations of Cushman and Parker from the Bastendorf shale of Oregon. Several Pacific Coast specimens which are strikingly similar have been illustrated and referred to various other species and careful study may prove some of them to be conspecific. One referred to *B. lirata* Cushman & Parker by Cushman and Simonson (1944, p. 198) from the Tumey formation of California seems similar to some immature specimens of the present species. Also, others from the Cowlitz formation of Washington (Beck, 1943, p. 605) and the Coaledo and Bastendorf formations of Oregon (Detling, 1946, p. 356) referred to *B. cuneata* (Cushman) appear similar to some of the Willapa Valley specimens. Variation, apparently among development stages, makes identification of specimens difficult, but specimens that seem to be mature are most similar to *B. sculptilis laciniata*.

Occurrence.—Lower part of the Willapa Valley section (Keasey equivalent), known previously from the Bastendorf and Keasey

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EXPLANATION OF PLATE 66

All specimens from Tertiary strata, Willapa River Valley, Pacific County, southwest Washington. Figures *1, 2, 3, 20, 21, 22* from the Oligocene-Miocene Blakeley(?) equivalent; *7, 8, 9, 12, 13*, Oligocene Keasey equivalent; *14, 15, 16, 17, 18, 19*, Miocene Astoria equivalent; all others Oligocene Lincoln equivalent.

FIGS. *1–3*—*Eponides umbonatus* Reuss. ×40. (p. 448)
4–6—*Gyroidina orbicularis planata* Cushman. ×40. (p. 447)
7–9—*Eponides minimus* Cushman. ×40. (p. 448)
10, 11—*Ellipsonodosaria* cf. *cocoaensis* (Cushman). ×20. (p. 446)
12, 13—*Eponides kleinpelli* Cushman & Frizzell. ×20. (p. 447)
14–16—*Eponides mansfieldi oregonensis* Cushman, Stewart & Stewart. ×40. (p. 447)
17–22—*Valvulineria menloensis* Rau, n. sp. Two syntypes. ×40. (p. 446)
23–25—*Valvulineria willapaensis* Rau, n. sp. Holotype. ×40. (p. 447)

formations of Oregon. *B. lirata*, from the Tumey formation of California and *B. cuneata*, from the Cowlitz formation of Washington and Coaledo and Bastendorf formations of Oregon, may be conspecific.

Figured Specimen.—USNM 547692.

BULIMINA sp.
Plate 65, figure 17

Test small, short, and relatively broad, initial end pointed, increasing rapidly in size to maximum thickness near apertural end, rounded and slightly lobate; chambers distinct, especially last three which are slightly more inflated; sutures distinct, slightly depressed; walls smooth except for fine costae over some two-thirds of the lower part of the test; aperture slightly curved, in sutural line between last two chambers at the terminus of the test. Minimum and maximum length, 0.40–0.59 mm.; breadth, 0.30–0.34 mm.; thickness, 0.28–0.33 mm.

This form seems to be distinct from any other previously described. *B. carnerosensis* Cushman & Kleinpell (1934, p. 5, pl. 1, figs. 12a, b) from the Miocene of California is similar but differs in being compressed and having coarse costae. Cushman and Parker's illustration and description of *B. inflata* Seguenza (1938, p. 58, pl. 10, figs. 4, 5) from the Pliocene of Italy suggests a strong resemblance except for the distinctly lipped aperture and costae covering most of the test. The Willapa Valley form may be a new species, but the material is insufficient to characterize it distinctly.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) equivalent].

Figured specimen.—USNM 547693.

Genus GLOBOBULIMINA Cushman, 1927

GLOBOBULIMINA HANNAI
Cushman & Ellisor
Plate 65, figure 13

Globobulimina hannai CUSHMAN & ELLISOR, 1945, Jour. Paleontology, vol. 19, p. 562, pl. 76, figs. 1a, b.

A few specimens seem to be essentially identical to this species. They differ from *G. pacifica* Cushman, as does the type of *G. hannai*, in being broader at the base, having sutures more deeply incised and the chambers more inflated.

Occurrence.—Middle part of the Willapa Valley section (Lincoln equivalent), known previously from the Anahuac formation of the Texas Oligocene.

Figured specimen.—USNM 547694.

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA ADVENA Cushman
Plate 65, figure 9

Bolivina advena CUSHMAN, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pt. 2, p. 29, pl. 5, figs. 1a, b; ——, 1937, idem, Special Pub. 9, p. 95, pl. 10, figs. 16a, b; KLEINPELL, 1938, Miocene Stratigraphy of California, p. 264, pl. 7, fig. 6; CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 1, p. 18, pl. 2, figs. 12a, b.

A small group of specimens are best referred to this species. Most of them have rather indistinct sutures but there is gradation to others with sutures noticeably limbate.

Occurrence.—Upper part of the Willapa Valley section (Astoria equivalent). Previously recorded from many Miocene localities of California (Saucesian to Mohnian). This species is also known from the Nye shale and Astoria formation in Oregon and from shale near Newport, Oregon. See Kleinpell (1938, p. 264) for some detailed occurrences on the Pacific Coast.

Figured specimen.—USNM 547695.

BOLIVINA FLORIDANA Cushman
Plate 65, figure 7

Bolivina floridana CUSHMAN, 1918, U. S. Geol. Survey Bull. 676, p. 49, pl. 10, fig. 4; ——, 1930, Florida Geol. Survey Bull. 4, p. 46, pl. 8, figs. 15a, b; —— & PARKER, 1931, Cushman Lab. Foram. Research Contr., vol. 7, pt. 1, p. 9, pl. 2, fig. 2; —— & CAHILL, 1933, U. S. Geol. Survey Prof. Paper 175A, p. 26, pl. 8, figs. 11a, b; ——, 1937, Cushman Lab. Foram Research Special Pub. 9, p. 85, pl. 10, figs. 2, 3.

Bolivina decussata CUSHMAN (not Brady), 1926, Cushman Lab. Foram. Research Contr., vol. 1, pt. 2, p. 31, pl. 5, figs. 6a, b.

A few specimens with highly undulant sutures and distinctly lobate chambers are best referred to this species. They seem essentially identical with specimens from the Temblor of California that have been illustrated by Cushman and Parker.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents]. Known previously from the Miocene of various parts of the world, mainly Florida, Trinidad, Venezuela, and from the Saucesian to Mohnian of the California Miocene.

Figured specimen.—USNM 547696.

BOLIVINA cf. JACKSONENSIS
Cushman & Applin
Plate 65, figure 8

A few very small specimens occur in several samples from the middle part of the section. They compare favorably with *B. jacksonensis* Cushman & Applin but as they are few and poorly preserved it is not possible to identify them positively.

Occurrence.—Middle part of the Willapa Valley section (Lincoln equivalent). *B. jacksonensis* is known from the upper Eocene and lower Oligocene of the Coastal Plain region of southeastern United States. It is also recorded from the Tertiary of Porto Rico and Mexico. See Cushman (1937, p. 57) for more detailed occurrences of this species.

Figured specimen.—USNM 547697.

BOLIVINA MARGINATA ADELAIDANA
Cushman & Kleinpell
Plate 65, figure 14

Bolivina marginata adelaidana CUSHMAN & KLEINPELL, 1934, Cushman Lab. Foram. Research Contr., vol. 10, pt. 1, p. 10, pl. 2, figs. 1, 2; CUSHMAN, 1937, idem, Special Pub. 9, p. 87, pl. 10, figs. 11–14; —— & MCCULLOCH, 1942, Allan Hancock Pacific Exped., vol. 6, no. 4, p. 200, pl. 24, figs. 2, 3; ——, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 1, p. 18, pl. 2, figs. 13a, b.

Numerous specimens agree in detail with the published description and illustrations of this form. The spinose periphery present on all specimens is better developed on some than on others. The sutures are definitely limbate but only slightly raised on most. *B. pisciformis* Galloway & Morrey is similar but differs because many specimens have a spine on the initial end and the test apparently tends to become narrower toward the apertural end.

Occurrence.—In numerous samples from the upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents]. This variety is known from the lower Saucesian (lower Miocene) of California and the Astoria formation of Oregon. See Kleinpell (1938, p. 277) for some detailed occurrences in the Pacific Coast Miocene. Also known from Recent sediments along the Pacific Coast.

Figured specimen.—USNM 547698.

Genus UVIGERINELLA Cushman, 1926
UVIGERINELLA CALIFORNICA ORNATA
Cushman
Plate 65, figure 15

Uvigerina (Uvigerinella) californica ornata CUSHMAN, 1926, Cushman Lab. Foram. Research Contr., vol. 2, pt. 3, p. 59, pl. 8, figs. 1a–c, 6.
Uvigerinella californica ornata CUSHMAN, STEWART & STEWART, 1930, San Diego Soc. Nat. History Trans., vol. 6, no. 2, p. 68, pl. 5, fig. 8; CUSHMAN & LAIMING, 1931, Jour. Paleontology, vol. 5, p. 111, pl. 12, figs. 9a, b; KLEINPELL, 1938, Miocene Stratigraphy of California, p. 288, pl. 8, fig. 8.

A few very finely costate specimens have all the essential characteristics of this form. Ornamentation is more pronounced on the early chambers but very faint costae also are present on the adult chambers of some.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents], known previously from the lower Saucesian to the upper Luisian of the California Miocene. See Kleinpell (1938, p. 288) for detailed occurrences.

Figured specimen.—USNM 547699.

UVIGERINELLA OBESA IMPOLITA
Cushman & Laiming
Plate 65, figure 18

Uvigerinella obesa impolita CUSHMAN & LAIMING, 1931, Jour. Paleontology, vol. 5, p. 111, pl. 12, figs. 11a, b; BARBAT & VON ESTORFF, 1933; idem, vol. 7, p. 171, pl. 23, figs. 10a, b; CUSHMAN & HOBSON, 1935, Cushman Lab. Foram. Research Contr., vol. 11, p. 62, pl. 9, figs. 6a, b; KLEINPELL, in Packard and Kellogg, 1934, Carnegie Inst. Washington Pub. 447, Contr. Paleontology, p. 18.

A few specimens from several samples from the upper part of the section agree in all essential respects with the type illustrations and description of this form. They seem quite distinct from *U. obesa* Cushman as the sutures are more deeply incised and there are fewer but coarser costae.

Occurrence.—Upper part of the Willapa

Valley section [Blakeley(?) and Astoria equivalents], known previously from the Zemorrian and Saucesian of California. This form is also recorded from the Nye shale of Oregon.

Figured specimen.—USNM 547700.

Genus UVIGERINA d'Orbigny, 1826

UVIGERINA ATWILLI Cushman & Simonson

Plate 65, figure 21

Uvigerina atwilli CUSHMAN & SIMONSON, 1944, Jour. Paleontology, vol. 18, p. 200, pl. 33, figs. 2–4; DETLING, 1946, idem, vol. 20, p. 357, pl. 50, figs. 5, 6.

A number of excellently preserved specimens agree in detail with Cushman and Simonson's published description and illustrations. Besides the characteristics mentioned by them, the present specimens display a noticeable irregularity in the addition of chambers. The early triserial stage frequently gives rise to a biserial stage and occasionally the last two chambers are arranged almost uniserially (see figured specimen).

Occurrence.—Lower part of the Willapa Valley section (Keasey equivalent). This species is also known from the upper part of the Bastendorf formation of Oregon and from the *Uvigerina cocoaensis* zone in the Tumey formation of California.

Figured specimen.—USNM 547701.

UVIGERINA cf. CARMELOENSIS Cushman & Kleinpell

Plate 65, figure 23

? *Uvigerina carmeloensis* CUSHMAN & KLEINPELL, 1934, Cushman Lab. Foram. Research Contr., vol. 10, pt. 1, p. 11, pl. 2, figs. 7a, b; CUSHMAN & TODD, 1941, idem, Contr., vol. 17, pt. 2, p. 44, pl. 13, fig. 10.

A few specimens compare favorably with the published description and illustrations of this species. The test is rather long and slender with the sides nearly parallel for much of the length. The chambers are moderately inflated and independently ornamented with fine, numerous, longitudinal costae. The neck, however, is considerably longer than shown on the previously published illustrations. Because of this identification is questionable.

Occurrence.—Upper part of the Willapa Valley section (Astoria equivalent). *U. carmeloensis* is known from the Monterey shale (lower Mohnian) of the California Miocene.

Figured specimen.—USNM 547702.

UVIGERINA COCOAENSIS Cushman

Plate 65, figure 28

Uvigerina cocoaensis CUSHMAN, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pt. 3, p. 68, pl. 10, fig. 12; —— & SCHENCK, 1928, California Univ., Dept. Geol. Sci. Bull. vol. 17, no. 9, p. 312, pl. 43, figs. 17–19; ——, 1935, U. S. Geol. Survey Prof. Paper 181, p. 39, pl. 15, figs. 11–13; —— & EDWARDS, 1937, Cushman Lab. Foram. Research Contr., vol. 13, p. 76, pl. 11, figs. 8, 9; —— & ——, 1938, idem, Contr., vol. 14, p. 89, pl. 14, figs. 15–17; —— & SIMONSON, 1944, Jour. Paleontology, vol. 18, p. 199, pl. 33, fig. 1; ——, 1946, Cushman Lab. Foram. Research Special Pub. 16, p. 28, pl. 5, figs. 15–20; DETLING, 1946, Jour. Paleontology, vol. 20, p. 357, pl. 50, fig. 7.

This species occurs abundantly in several samples from the lower part of the section. The specimens display considerable variation in shape and size as well as in number and distribution of costae. The presence of this species in the Willapa Valley section suggests that part of it may be equivalent to the *Uvigerina cocoaensis* zone of California.

Occurrence.—Lower part of the Willapa Valley section (Keasey and Lincoln equivalents), known previously from many upper Eocene localities of the Gulf Coastal Plain area of the United States. This species is well known on the Pacific Coast where it occurs in the *Uvigerina cocoaensis* zone of the Tumey formation of California and the Coaledo and Bastendorf formations of Oregon.

Figured specimen.—USNM 547703.

UVIGERINA GALLOWAYI Cushman

Plate 65, figure 24

Uvigerina gallowayi CUSHMAN, 1929, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 94, pl. 13, figs. 33, 34; —— & EDWARDS, 1938, idem, Contr., vol. 14, pt. 4, p. 75, pl. 13, figs. 8, 9; KLEINPELL, 1938, Miocene stratigraphy of California, p. 294, pl. 5, figs. 1, 2, 5; CUSHMAN & TODD, 1941, Cushman Lab. Foram. Research Contr., vol. 17, p. 45, pl. 13, fig. 11; CUSHMAN & SIMONSON, 1944, Jour. Paleontology, vol. 18, p. 200, pl. 32, figs. 18, 19.

This species occurs abundantly in a single sample from the upper part of the section. It seems to be quite variable as the length

of the test and the number and extent of the longitudinal costae are not at all constant. Therefore, it is rather difficult to distinguish from *U. cocoaensis*, also a variable species, which occurs in samples from the lower part of the section. However, in most specimens the last few chambers of *U. gallowayi* are more costate than are those of *U. cocoaensis*.

Occurrence.—Upper part of the Willapa Valley section [Lincoln and Blakeley(?) equivalents]. This species has been recorded previously from the probable upper Oligocene of Ecuador and Venezuela. It is also known from the Tumey formation as well as a number of other localities of California. See Kleinpell (1938, p. 294) for some detailed occurrences on the Pacific Coast.

Figured specimen.—USNM 547704.

UVIGERINA GARZAENSIS Cushman & Siegfus
Plate 65, figure 19

Uvigerina garzaensis CUSHMAN & SIEGFUS, 1939, Cushman Lab. Foram. Research Contr., vol. 15, pt. 2, p. 28, pl. 6, figs. 15a, b; CUSHMAN & SIMONSON, 1944, Jour. Paleontology, vol. 18, p. 199, pl. 32, figs. 20, 21; DETLING, 1946, idem, vol. 20, p. 357, pl. 50, fig. 8.

The development of hispid structure on the walls of the present specimens is somewhat variable. A few individuals are practically smooth whereas the walls of others are quite noticeably roughened, but there is gradation between the two extremes. These specimens are quite similar to the published description and illustrations of *U. garzaensis* Cushman & Siegfus.

Occurrence.—Lower part of the Willapa Valley section (Keasey equivalent). This species was originally described from the Eocene Kreyenhagen shale of California. It has since been recorded from the lower Oligocene Tumey formation of California and the Coaledo and Bastendorf formations of Oregon.

Figured specimen.—USNM 547705.

Genus SIPHOGENERINA Schlumberger, 1883

SIPHOGENERINA TRANSVERSA Cushman
Plate 65, figures 25–27

Siphogenerina transversa CUSHMAN & PARKER, 1931, Cushman Lab. Foram. Research Contr., vol. 7, pt. 1, p. 10, pl. 2, figs. 5, 6; CUSHMAN & LAIMING, 1931, Jour. Paleontology, vol. 5, p. 112, pl. 12, fig. 13; KLEINPELL in Packard and Kellogg, 1934, Carnegie Inst. Washington Pub. 447, Contr. Paleontology, p. 17; ——, 1938, Miocene Stratigraphy of California, p. 305.

A very common form in many of the samples from the upper part of the section probably is best referred to this species. The specimens have an internal case that is probably silicious as it is insoluble in hydrochloric acid but the external portion is calcareous and dissolves completely. A few specimens reveal the internal structure (see pl. 65, fig. 27) and show that the early chambers are arranged in a slightly spiral manner and that the sutures are quite strongly bent. Complete specimens vary greatly in length and are ornamented with ten to 12 distinct plate-like longitudinal costae. *Siphogenerina collomi*, *S. kleinpelli*, *S. branneri* and *S. transversa*, recorded from the Pacific Coast Miocene, have many similar features and examination of type material would probably be necessary to distinguish between them. The published illustration and description of typical *S. collomi* (Cushman, 1925, p. 2, pl. 4, fig. 3) indicate specimens relatively broader through the middle portion than the Willapa forms but Kleinpell's illustration (1938, p. 300, pl. 15, fig. 11) is very similar. *S. collomi* seems to be restricted to a zone higher in the Miocene than that occupied by the Willapa specimens. Typical *S. kleinpelli* (Cushman, 1925, p. 3, pl. 4, fig. 5) differs by having more and lower costae, but Kleinpell (1938, p. 301) pointed out that numerous specimens collected from a similar locality possess ten or 11 costae. The stratigraphic zone suggested by the fossils associated with the Willapa Valley *Siphogenerina* coincides reasonably well with the previously recorded occurrence of *S. kleinpelli*. Figures of *S. branneri* suggest that that species is more distinct from the Willapa Valley specimens than are any of the others mentioned. It usually has more and probably finer costae and the sutures are not as deeply incised.

These comparisons indicate that detailed study of the Pacific Coast Miocene species of *Siphogenerina* is needed. Until this is done the Willapa Valley specimens are referred to *S. transversa* as they seem to agree with its typical representatives most closely.

Kleinpell (1938, p. 305) lists the synonymy of *S. transversa*, so it is not duplicated here.

Occurrence.—Upper part of the Willapa Valley section (Astoria equivalent). *S. transversa* is known from the Zemorrian and Saucesian of the California Miocene. It is also recorded from the Astoria shale of Oregon and is known in the tropical Americas from the Tertiary of Trinidad, Venezuela, and the Panama Canal Zone.

Figured specimen.—USNM 547706.

Family ELLIPSOIDINIDAE
Genus ELLIPSONODOSARIA Silvestri, 1900
Genus ELLIPSONODOSARIA cf.
COCOAENSIS (Cushman)
Plate 66, figures 10, 11

Nodosaria cocoaensis CUSHMAN, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pt. 3, p. 66, pl. 10, figs. 5, 6.
Nodosaria sp. CUSHMAN & APPLIN, 1926, Am. Assoc. Petroleum Geologists Bull., vol. 10, p. 170, pl. 7, fig. 17.
Dentalina cocoaensis CUSHMAN, 1927, Jour. Paleontology, vol. 1, p. 153, pl. 24, fig. 14; ELLISOR, 1933, Am. Assoc. Petroleum Geologists Bull., vol. 17, pl. 2, fig. 5; CUSHMAN, 1935, U. S. Geol. Survey Prof. Paper 181, p. 19, pl. 8, figs. 1, 2.
Ellipsonodosaria cocoaensis CUSHMAN, 1939, Cushman Lab. Foram. Research Contr., vol. 15, pt. 3, p. 68, pl. 11, figs. 27–33; ——, 1946, idem, Special Pub. 16, p. 30, pl. 6, fig. 10.
Ellipsonodosaria cf. *cocoaensis* BECK, 1943, Jour. Paleontology, vol. 17, p. 608, pl. 108, fig. 10.,

Two general forms of this species occur in the Willapa Valley material. One is essentially identical to Beck's figure, as it is blunt on the initial end with a spine nearest the concave side of the arcuate test. The other tapers to a pointed initial end. The adult chambers, however, are similar and these two groups are believed to be megalospheric and microspheric forms of a single species. Similarity to *E. verneuili* (d'Orbigny), mentioned by both Cushman and Beck, is also apparent in the Willapa Valley specimens.

Occurrence.—Lower and middle parts of the Willapa Valley section (Keasey and Lincoln equivalents). This species is known from the type Cowlitz of southwest Washington and the upper Eocene of Texas and southeastern United States. It is also recorded from the Alazan clays of Mexico.

Figured specimen.—USNM 547707.

Family ROTALIIDAE
Genus VALVULINERIA Cushman, 1926
VALVULINERIA ARAUCANA (d'Orbigny)
Plate 67, figures 18–20

Rosalina araucana D'ORBIGNY, 1839, Voyage dans l'Amerique Méridionale, tome 5, pt. 5, p. 44, pl. 6, figs. 16–18.
Valvulineria araucana CUSHMAN, 1927, Bull. Scripps Inst. Oceanography, Tech. Ser., vol. 1, no. 10, p. 160, pl. 4, figs. 7, 8; ——, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 1, p. 20, pl. 3, figs. 1a–c.

Numerous specimens agree closely with illustrations and descriptions of this species. They are especially similar to those figured by Cushman, Stewart and Stewart from the Astoria of Oregon. These authors (1947, p. 20) list the synonymy of the species which is not duplicated here.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents]. This species was originally described from off the coast of Chile and is now widely known from the Recent and Tertiary. It is especially common in the Miocene of California and has been recorded from the Astoria of Oregon.

Figured specimen.—USNM 547708.

VALVULINERIA MENLOENSIS Rau, n. sp.
Plate 66, figures 17–22

Test slightly longer than broad, unequally biconvex, with periphery acute throughout; chambers distinct, ten to 15 in last whorl, increasing in size only slightly as added, depressed in much of the early portion, last few chambers only slightly inflated; sutures distinct, extremely limbate, usually raised throughout and curved back considerably; walls finely perforate and frequently with a series of coarse foramens surrounding the umbilical region on the ventral side, but this is not always obvious on unweathered specimens; aperture ventral, beneath a distinct valve. Minimum and maximum length, 0.69–0.83 mm.; breadth, 0.59–0.69 mm.; thickness, 0.31–0.39 mm.

Insofar as the writer has observed, this species seems quite distinct from any previously described. It is similar to *V. casitasensis subcasitasensis* Kleinpell, but has more strongly limbate and raised sutures, more numerous chambers in the last whorl,

and the foramen system about the ventral umbilicus seems more distinct.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents].

Syntypes.—USNM 547709.

VALVULINERIA WILLAPAENSIS Rau, n. sp.
Plate 66, figures 23–25

Test large, strongly compressed, somewhat longer than broad, nearly equally biconvex with an acute periphery and a distinct knob in the umbonal region on the dorsal side; chambers numerous, about 14 in last whorl, not uniformly increasing in size as added; sutures distinct, strongly limbate, definitely raised and curved; walls smooth, shiny but distinctly perforate; aperture a large opening at the periphery, extending to the umbilical region of the ventral side but largely covered there by a distinct valve. Minimum and maximum length, 0.71–1.18 mm.; breadth, 0.55–0.98 mm.; thickness, 0.22–0.33 mm.

As far as the writer is able to ascertain, this species is quite unlike any previously described. The large compressed test, distinct dorsal knob, strongly limbate sutures and very well developed valve in the umbilical region are distinguishing features. The highly compressed test and general arrangement of chambers is somewhat similar to *Planulina* but the pronounced valve over much of the aperture in the umbilical region of the ventral side is indicative of *Valvulineria*.

Occurrence.—Lower part of the Willapa Valley section (Lincoln equivalent).

Hypotype.—USNM 547710.

Genus GYROIDINA d'Orbigny, 1826
GYROIDINA ORBICULARIS PLANATA
Cushman
Plate 66, figures 4–6

Gyroidina orbicularis planata CUSHMAN, 1935, U. S. Geol. Survey Prof. Paper 181, p. 45, pl. 18, figs. 3a–c; —— & SIEGFUS, 1942, San Diego Soc. Nat. History Trans., vol. 9, p. 419, pl. 17, fig. 32; —— & FRIZZELL, 1942, Cushman Lab. Foram. Research Contr., vol. 19, pt. 4, p. 87, pl. 15, figs. 2–4; RAU, 1948, Jour. Paleontology, vol. 22, p. 171, pl. 31, figs. 12–14.

Considerable size variation is displayed by numerous specimens of this variety. The outermost coil falls either slightly below or above or in some specimens even with the previous plane of coiling on the dorsal surface. Such variations were noted by Cushman in his original description. Specimens referred to this variety from the Porter shale of Washington are essentially identical. Specimens referred to as *Gyroidina* cf. *soldanii* d'Orbigny from the Coaledo formation of Oregon (Detling, 1946, p. 358, pl. 50, figs. 13a–c) also are similar.

Occurrence.—Middle part of the Willapa Valley section [Keasey, Lincoln and Blakeley(?) equivalents]. This variety is known from the Jackson formation of South Carolina, the Kreyenhagen shale of California and the Lincoln formation (type locality) and Porter shale of Washington.

Figured specimen.—USNM 547711.

Genus EPONIDES Montfort, 1808
EPONIDES KLEINPELLI
Cushman & Frizzell
Plate 66, figures 12, 13

Eponides kleinpelli CUSHMAN & FRIZZELL, 1940, Cushman Lab. Foram. Research Contr., vol. 16, pt. 2, p. 42, pl. 8, figs. 11a–c; RAU, 1948, Jour. Paleontology, vol. 22, p. 172, pl. 31, figs. 6–8.

A few specimens are similar in all essential respects to the published description and illustrations of this species. Specimens examined from the Porter shale of Washington are practically identical with those from the Willapa Valley.

Occurrence.—Lower part of the Willapa Valley section (Keasey equivalent), known previously from the Lincoln formation (type locality) and the Porter shale of Washington.

Figured specimen.—USNM 547712.

EPONIDES MANSFIELDI OREGONENSIS
Cushman, Stewart & Stewart
Plate 66, figures 14–16

Eponides mansfieldi CUSHMAN & PARKER, 1931 [not Cushman, 1930], Cushman Lab. Foram. Research Contr., vol. 7, pt. 1, p. 12, pl. 2, figs. 10a–c.

Eponides mansfieldi oregonensis CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 2, p. 48, pl. 6, figs. 4a–c.

A few specimens perhaps are referred best to this variety rather than to the typical variety. Although they vary considerably, most of them are only slightly

papillate on the ventral surface and the sutures are not raised. These features are rather characteristic.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents]. This variety was originally described from the Astoria beds of Lincoln County in western Oregon and it is also known from the Miocene Temblor formation of California.

Figured specimen.—USNM 547713.

EPONIDES MINIMUS Cushman
Plate 66, figures 7–9

Eponides minima CUSHMAN, 1933, Cushman Lab. Foram. Research Contr., vol. 9, pt. 1, pl. 17, pl. 2, figs. 8a–c; ——, 1935, U. S. Geol. Survey Prof. Paper 181, p. 47, pl. 19, fig. 3a–c; —— & MCMASTERS, 1936, Jour. Paleontology, vol. 10, p. 514, pl. 76, figs. 2a–c.

Eponides minimus BECK, 1943, Jour Paleontology, vol. 17, p. 608, pl. 108, figs. 16, 17, 19; CUSHMAN, 1945, Cushman Lab. Foram. Research Contr., vol. 21, pt. 1, p. 9, pl. 2, figs. 12a–c; ——, 1946, idem, Special Pub., 16, p. 34, pl. 6, fig. 17; ——, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 5, p. 103, pl. 13, figs. 10a–c.

Very small and rather common specimens from the lower part of the section compare closely with published figures of this species. *E. vicksburgensis* Cushman & Ellisor (1931, p. 56, pl. 7, figs. 8a–c) is also similar but papillae of the ventral surface seem to be more pronounced. Some of the Willapa Valley specimens are completely devoid of such ornamentation.

Occurrence.—Lower part of the Willapa Valley section (Cowlitz and Keasey equivalents). Known previously from the upper Eocene Jackson formation of the Atlantic-Gulf Coastal Plain, the Llajas of California, the Cowlitz of Washington (Lewis County) and the Helmick of Oregon.

Figured specimen.—USNM 547714.

EPONIDES UMBONATUS (Reuss)
Plate 66, figures 1–3

Rotalina umbonata REUSS, 1851, Deutsche geol. Gesell. Zeitschr., Bd. 3, p. 75, pl. 5, figs. 35a–c.

Pulvinulina umbonata HANTKEN, 1875 (1876), Magyar kir. földt. int. Evkön., vol. 4, p. 67, pl. 9, fig. 8.

Rotalia umbonata GALLOWAY & MORREY, 1929, Bull. Am. Paleontology, vol. 15, no. 55, p. 26, pl. 4, figs. 1a–c.

Rotalia ecuadorensis GALLOWAY & MORREY, 1929, Bull. Am. Paleontology, vol. 15, no. 55, p. 26, pl. 3, figs. 13a–c.

Eponides umbonatus ecuadorensis HEDBERG, 1937, Jour. Paleontology, vol. 11, p. 679, pl. 91, fig. 22.

Eponides umbonata CUSHMAN, 1929, Cushman Lab. Foram. Research Contr., vol. 5, pt. 4, p. 98, pl. 14, figs. 8a–c.

Eponides umbonatus KLEINPELL, 1938, Miocene Stratigraphy of California, p. 322, pl. 6, figs. 9, 12; FRANKLIN, 1944, Jour. Paleontology, vol. 18, p. 316, pl. 47, figs. 5a–c; CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 1, p. 21, pl. 3, figs. 2, 3.

A few specimens from the middle part of the section are quite similar to the numerous published illustrations and descriptions of this species. The sutures of the ventral

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EXPLANATION OF PLATE 67

All specimens from Tertiary strata, Willapa River Valley, Pacific County, southwest Washington. Figures *1, 2, 11, 12, 13* from Oligocene-Miocene Blakeley(?) equivalent; *3, 4, 6, 8*, Oligocene Lincoln equivalent; *5, 9, 10, 15, 16, 17*, Oligocene Keasey equivalent; *26, 27, 28, 29, 30*, Eocene Cowlitz equivalent; all others Miocene Astoria equivalent.

FIGS. *1, 2*—*Pseudoparrella parva* (Cushman & Laiming). ×40. (p. 449)

3–5—*Cassidulina globosa* Hantken. Two specimens; *3, 4*, compressed form; *5*, typical form; ×40. (p. 449)

6—*Cassidulina galvinensis* Cushman & Frizzell. ×40. (p. 449)

7—*Cassidulina pulchella* d'Orbigny. ×40. (p. 450)

8—*Chilostomella* cf. *oolina* Schwager. ×40. (p. 450)

9, 10—*Pullenia salisburyi* Stewart & Stewart. ×40 (p. 450)

11–13—*Anomalina?* sp. ×40. (p. 451)

14—*Globigerina bulloides* d'Orbigny. ×40. (p. 450)

15–17—*Cibicides elmaensis* Rau. ×40. (p. 451)

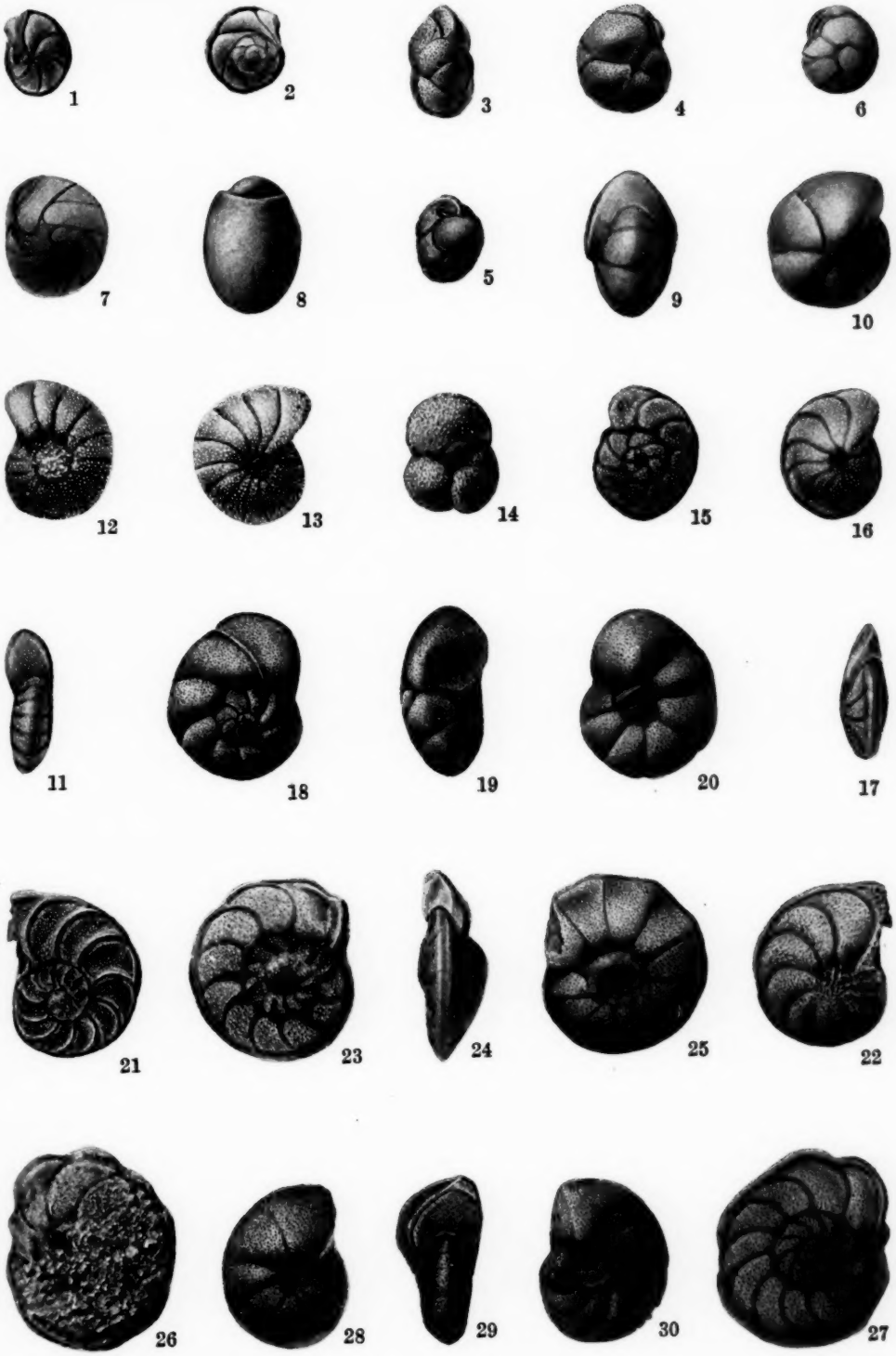
18–20—*Valvulineria araucana* (d'Orbigny). ×40. (p. 446)

21, 22—*Planulina astoriensis* Cushman, Stewart & Stewart. ×40. (p. 451)

23–25—*Cibicides* aff. *perlucida* Nuttal. ×40. (p. 452)

26, 27—*Cibicides natlandi* Beck. ×40. (p. 452)

28–30—*Cibicides hodgei* Cushman & Schenck. ×40. (p. 451)



Rau, Washington Tertiary Foraminifera

side are characteristically curved near the umbilicus, whereas those of the dorsal side are straight and somewhat radiate. A few specimens from a single locality in the lower part of the section are questionably referred to this species.

Occurrence.—Middle and possibly lower parts of the Willapa Valley section [Lincoln, Blakeley(?) and possibly Keasey equivalents]. This species is known to be widely distributed both geographically and stratigraphically from middle Eocene possibly to the Recent. It has been recorded from the type Blakeley in Washington, the Astoria formation in Oregon and the lower Miocene of California. It is also known from Mexico, Ecuador, Venezuela and Europe.

Figured specimen.—USNM 547715.

Family CASSIDULINIDAE
Genus PSEUDOPARRELLA Cushman & ten Dam, 1948
PSEUDOPARRELLA PARVA (Cushman & Laiming)
Plate 67, figures 1, 2

Pulvinulinella parva CUSHMAN & LAIMING, 1931, Jour. Paleontology, vol. 5, p. 115, pl. 13, figs. 5a–c; CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 2, p. 48, pl. 6, figs. 5a–c; RAU, 1948, Jour. Paleontology, vol. 22, p. 780, pl. 119, figs. 12–14.

Pulvinulinella cf. *smithi* CUSHMAN & PARKER, 1931, Cushman Lab. Foram. Research Contr., vol. 7, pt. 1, p. 14, pl. 2, figs. 12a–c.

This species is represented by numerous typical specimens. The ventral side is strongly convex, the dorsal surface is nearly flat with only a slight elevation of the umbonal region and the keel is well developed. Six chambers are commonly present in the last whorl. The ventral sutures are slightly curved but those of the dorsal side are nearly straight and oblique. These fossils correspond in practically every respect with specimens from the Astoria formation in Washington (Rau, 1948b, p. 780, pl. 119, figs. 12–14).

Cushman and ten Dam (1948, p. 49) found that the generic name *Pulvinulinella* Cushman, 1926, is preoccupied by *Pulvinulinella* Eimer & Fickert, 1899. They proposed *Pseudoparrella* as a substitute name for Cushman's genus.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents], known previously from the Zemorrian and Saucesian of the California Miocene. This species is also recorded from the Astoria shale of Oregon and Washington and the type Blakely of Washington.

Figured specimen.—USNM 547716.

Genus CASSIDULINA d'Orbigny, 1826
CASSIDULINA GALVINENSIS Cushman & Frizzell
Plate 67, figure 6

Cassidulina galvinensis CUSHMAN & FRIZZELL, 1940, Cushman Lab. Foram. Research Contr., vol. 16, pt. 2, p. 43, pl. 8, figs. 10a–c; RAU, 1948, Jour. Paleontology, vol. 22, p. 173, pl. 31, figs. 9–11.

Several somewhat compressed specimens compare closely with the description and illustrations of the type of this species. Chambers are added nearly at right angles to each other and show very little, if any, inflation. Sutures are slightly limbate and practically flush with the surface. These features are characteristic. Also, the Willapa Valley fossils are essentially identical with specimens referred to this species from the Porter shale of Washington.

Occurrence.—Middle part of the Willapa Valley section [Lincoln and Blakeley(?) equivalents], known previously from the Lincoln formation (type locality) and the Porter shale of Washington.

Figured specimen.—USNM 547717.

CASSIDULINA GLOBOSA Hantken
Plate 67, figures 3–5

Cassidulina globosa HANTKEN, 1875 (1876), Mogyr. kir. földt. int. Evkön, vol. 4, p. 54, pl. 16, fig. 2; BECK, 1943, Jour. Paleontology, vol. 17, p. 609, pl. 108, figs. 7, 13, 14; CUSHMAN & SIMONSON, 1944, idem, vol. 18, p. 202, pl. 34, fig. 7; DETLING, 1946, idem, vol. 20, p. 358, pl. 51, figs. 3a, b; CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 4, p. 79, pl. 10, figs. 10a, b; pt. 5, p. 103, pl. 12, figs. 14a, b.

A few specimens from scattered localities in the lower part of the section are best referred to this species. All are small, but they vary considerably in size. Moreover, the smaller specimens display the greatest rotundity. The larger specimens are somewhat compressed but their chambers are more noticeably inflated (see figured speci-

mens). Cushman, Stewart and Stewart (1947, p. 103) list the synonymy and this is not repeated here.

Occurrence.—Lower part of the Willapa Valley section (Cowlitz, Keasey and Lincoln equivalents). This species has a wide geographic distribution in both the upper Eocene and lower Oligocene, being known from Europe, Peru, Mexico, the Gulf Coastal Plain of the southeastern United States, California and Oregon.

Figured specimens.—USNM 547718.

CASSIDULINA PULCHELLA d'Orbigny
Plate 67, figure 7

Cassidulina pulchella CUSHMAN, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pt. 2, p. 34, pl. 5, fig. 6; RAU, 1948, Jour. Paleontology, vol. 22, p. 780, pl. 119, figs. 21–23.
Cassidulina cf. *pulchella* KLEINPELL, 1938, Miocene Stratigraphy of California, p. 336, pl. 17, figs. 14, 15.

Numerous specimens occur in many of the samples from the upper part of the section that compare closely with those previously recorded from the Washington Miocene as this species. There is some question, however, as to their identity with the type, and numerous other specimens referred to the species. Recently the writer (1948b, p. 780) discussed this species.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents], known previously from the Astoria formation of Washington. Forms seeming identical are also known from the Miocene of California. Other specimens referred to this species are from the Pliocene of California and Recent deposits off the Pacific Coast.

Figured specimen.—USNM 547719.

Family CHILOSTOMELLIDAE
Genus CHILOSTOMELLA Reuss, 1850
CHILOSTOMELLA cf. OOLINA Schwager
Plate 67, figure 8

?Chilostomella oolina SCHWAGER, 1878, Com. geol. ital. Boll., vol. 9, p. 527, pl. 1, fig. 16.

A few rather long narrow specimens compare favorably with *C. oolina* Schwager. Most of them are relatively more slender than the specimen figured here. The aperture is a long, broad, lipped opening normal to the elongation of the test. The small number of rather poorly preserved specimens makes positive identification impossible.

Occurrence.—Lower and middle parts of the Willapa Valley section (Cowlitz, Keasey, and Lincoln equivalents). *C. oolina* is known from many localities in various parts of the world, especially Venezuela, the Gulf Coastal Plain of southeastern United States, and California. The species is known to range from Oligocene to Recent.

Figured specimen.—USNM 547720.

Genus PULLENIA Parker & Jones, 1862
PULLENIA SALISBURYI Stewart & Stewart
Plate 67, figures 9, 10

Pullenia salisburyi STEWART & STEWART, 1930, Jour. Paleontology, vol. 4, p. 72, pl. 8, figs. 2a, b; CUSHMAN & MOYER, 1930, Cushman Lab. Foram. Research Contr., vol. 6, pt. 3, p. 61, pl. 8, figs. 13a, b; CUSHMAN & LAIMING, 1931, Jour. Paleontology, vol. 5, p. 117, pl. 14, figs. 2a, b; CUSHMAN & PARKER, 1931, Cushman Lab. Foram. Research Contr., vol. 7, pt. 1, p. 15, pl. 2, figs. 15a, b; CUSHMAN, 1933, idem, Special Pub. 5, pl. 33, figs. 18a, b; BECK, 1943, Jour. Paleontology, vol. 17, p. 609, pl. 108, figs. 8, 12.

A few specimens from the lower part of the section agree closely with the published descriptions and illustrations of this species. The six chambers in the last whorl are all somewhat inflated, the sutures are slightly curved and the walls are finely perforate. Although the aperture is not distinct, it appears to be at the base of the last septal face.

Occurrence.—Lower part of the Willapa Valley section (Keasey equivalent). This species has a wide stratigraphic range on the Pacific Coast. It is known from the Miocene, Pliocene and Recent sediments of California and has been recorded from the type Cowlitz of Washington.

Figured specimen.—USNM 547721.

Family GLOBIGERINIDAE
Genus GLOBIGERINA d'Orbigny, 1826
GLOBIGERINA BULLOIDES d'Orbigny
Plate 67, figure 14

Globigerina bulloides D'ORBIGNY, 1826, Annales sci. nat., sér. 1, tome 7, p. 277; Modeles, no. 17 and 76.

Samples from the upper part of the section have yielded numerous specimens ornamented with a hispid-like structure. Four

chambers are visible on the ventral side and all chambers may be seen dorsally, but only the last five are well defined. These specimens seem to coincide almost precisely with numerous illustrations of this common species.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents], known previously from the Eocene to the Recent in many parts of the world. See Ellis and Messina (1940–1950) for references.

Figured specimen.—USNM 547722.

Family ANOMALINIDAE
Genus ANOMALINA d'Orbigny, 1826
ANOMALINA? sp.
Plate 67, figures 11–13

Test compressed, of medium size, nearly biconvex, but somewhat flatter ventrally than dorsally, periphery rounded; chambers distinct, ten to 12 in last whorl, not inflated; sutures distinct, especially last few, slightly curved backward, flush with surface; walls polished but coarsely perforate; aperture indistinct, seemingly at the base of the last septal face at the periphery. Minimum and maximum length, 0.48–0.55 mm.; breadth, 0.36–0.45 mm.; thickness, 0.18–0.20 mm.

Several specimens from the upper part of the section have not been generically identified because detailed features and especially the apertural characteristics are indistinct. General appearance, however, suggests that they belong in *Anomalina*, although they might be referable to *Cibicides*. Kleinpell (1938, p. 356, pl. 6, figs. 13, 18, 21) recorded a form as *Cibicides*(?) sp. from the Vaqueros formation of California which is similar.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) equivalent].

Figured specimen.—USNM 547723.

Genus PLANULINA d'Orbigny, 1826
PLANULINA ASTORIENSIS Cushman, Stewart & Stewart
Plate 67, figures 21, 22

Planulina astoriensis CUSHMAN, STEWART & STEWART, 1947, Oregon State Dept. Geology and Min. Industries Bull. 36, pt. 1, p. 23, pl. 4, figs. 4, 5.

A few specimens agree closely with the description and illustrations of this species. The test is strongly compressed and the sutures are distinctly limbate. All whorls are visible dorsally but only part of the last two may be seen on the ventral side. The walls are coarsely perforate.

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents]. This species was originally described from the type Astoria formation of Oregon. The authors of this species noted that it occurs abundantly and suggested that it might be a good index fossil.

Figured specimen.—USNM 547724.

Genus CIBICIDES Montfort, 1808
CIBICIDES ELMAENSIS Rau
Plate 67, figures 15–17

Cibicides elmaensis RAU, 1948, Jour. Paleontology, vol. 22, p. 173, pl. 31, figs. 18–26.

This extremely variable species is well represented in a number of samples from the Willapa Valley area. The convexity of both the dorsal and ventral surfaces perhaps is the most inconsistent feature. The writer (1948a, p. 173) recently discussed this species.

Occurrence.—Lower and middle parts of the Willapa Valley section [Keasey, Lincoln and Blakeley(?) equivalents], known previously from the Porter shale of Washington.

Figured specimen.—USNM 547725.

CIBICIDES HODGEI Cushman & Schenck
Plate 67, figures 28–30

Cibicides hodgei CUSHMAN & SCHENCK, 1928, California Univ., Dept. Geol. Sci. Bull., vol. 17, no. 9, p. 315, pl. 45, figs. 3, 5; BECK, 1943, Jour. Paleontology, vol. 17, p. 611, pl. 109, figs. 24–28; CUSHMAN & SIMONSON, 1944, idem, vol. 18, p. 202, pl. 34, figs. 14, 15; DETLING, 1946, idem, vol. 20, p. 359, pl. 51, figs. 6a–c, 8a–c.

Samples from the lower part of the section have yielded fossils which compare closely with the published description and illustrations of this species. They have a somewhat flattened dorsal surface, the last few chambers are considerably enlarged, and sutures are distinctly limbate.

Occurrence.—Lower part of the Willapa Valley section (Cowlitz and Keasey equivalents), known previously from the Bastendorf formation and the Keasey shale of Oregon, the Tumey formation of California, and the type Cowlitz of Washington.

Figured specimen.—USNM 547726.

CIBICIDES NATLANDI Beck
Plate 67, figures 26, 27

Cibicides natlandi BECK, 1943, Jour. Paleontology, vol. 17, p. 612, pl. 109, figs. 1, 5, 13.

A number of specimens from the lower part of the section are almost certainly conspecific with *C. natlandi* Beck. The ventral sutures are obscured by beaded shell material and the periphery is distinctly keeled. This species is considered to be a good index fossil for the Cowlitz.

Occurrence.—Lowest part of the Willapa Valley section (Cowlitz equivalent). This species is known from the type Cowlitz of southwest Washington and the upper type Tejon formation of California.

Figured specimen.—USNM 547727.

CIBICIDES aff. PERLUCIDA Nuttall
Plate 67, figures 23–25

Cibicides aff. *perlucida* RAU, 1948, Jour. Paleontology, vol. 22, p. 781, pl. 119, figs. 15–17.

A few specimens from scattered localities in the upper part of the section compare in detail with specimens from the Washington Miocene. A discussion of this form was published recently by the writer (1948b, p. 781).

Occurrence.—Upper part of the Willapa Valley section [Blakeley(?) and Astoria equivalents], recorded previously from the Astoria formation in Washington. Kleinpell has also reported a similar form from the lower Miocene of California.

Figured specimen.—USNM 547728.

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LOWER MISSISSIPPIAN AMMONOIDS OF MISSOURI

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ABSTRACT—Ammonoids are not rare in the Chouteau limestone and the Northview shale of Missouri, and a few specimens are also known from the Louisiana limestone and the Hannibal shale. Altogether, these strata have yielded representatives of six genera: *Imitoceras*, *Gattendorfia*, *Munsteroceras*, *Pericyclus*, *Protocanites* and *Prodromites*. Each genus is discussed at some length, and the Lower Mississippian species that are known from Missouri and adjacent portions of Iowa and Illinois are described and most of them are illustrated.

SOME years ago, the late Professor E. B. Branson undertook the preparation of a detailed report on the Lower Mississippian stratigraphy and paleontology of Missouri (exclusive of the Louisiana limestone). Much of the work was done in collaboration with his colleagues and advanced students. The cephalopods were studied during the years 1928, 1929 and 1930 by the senior author of the present paper, but when Branson's report was issued in 1938, it was possible for him (with the help of W. M. Furnish) to revise for publication only the portion of his manuscript which dealt with the nautiloids. Little, therefore, has been published in regard to the ammonoids which occur in these strata since the appearance in 1903 of J. P. Smith's classical monograph, *The Carboniferous ammonoids of America*.

Some 20 years have elapsed since the manuscript by Miller was completed. During this time a great deal of progress has been made in the understanding of Mississippian cephalopods, and a considerable amount of additional material has been added to the collections under consideration. Accordingly, the present report is essentially a new and independent work and all of the illustrations have been remade. Furthermore, we have included a study of the few specimens that are known from related strata at nearby localities in Iowa and Illinois.

The oldest ammonoids that have been described from Missouri are those of the Louisiana limestone, which is confined to the northeastern portion of the state (and the adjacent part of Illinois). In 1943 Williams published a detailed study of this formation and its fauna. He stated that it varies up to more than 50 feet in thickness and that it lies between the Saverton and the Hannibal shales, which he regarded as of early Mississippian age. Some other authors have placed the Louisiana in the Devonian. The few goniatites that it has yielded, *Imitoceras compressum* (Moore) and *Protocanites? louisianensis* (Rowley), can hardly be said to fix its age, but they indicate that it belongs in the Mississippian rather than the Devonian.

The Hannibal shale occurs in the same general region as the Louisiana. Its lithology is quite variable and so is its thickness, which ranges up to more than 100 feet. Over much of its areal extent this formation is silty. It has so far yielded only one goniatite. Although this specimen is but moderately well preserved, it clearly belongs in the genus *Imitoceras* and is closely related to congeneric forms which occur in the Louisiana and the Chouteau. It is quite in harmony with the early Mississippian age that is generally attributed to the Hannibal.

Most of the Lower Mississippian ammonoids that have been collected in Missouri came from the Chouteau limestone, which outcrops in an almost continuous belt extending from the northeastern to the southwestern portion of the state. There has been considerable difference of opinion as to just what should be included in this formation, and the names Compton, Fern Glen, Northview, Pierson, Reeds Spring and Sedalia have been used for portions or facies of it as interpreted by Branson in 1938 and 1944. Inasmuch as most of the collections we are studying were assembled and labelled by Branson and his associates, we are following

his stratigraphic terminology, more or less of necessity, except for the Fern Glen, Pierson and Reeds Spring, all of which we believe to be early Osage. That is, we are placing in the Chouteau formation the lower portion of the Mississippian of central and southwestern Missouri up to and including the top of the Northview shale, and all but the uppermost part of the Sedalia of Moore (1928, p. 149) belongs in the Chouteau as we interpret that formation. It seems to us that the ammonoids carried by these beds almost certainly represent only one fauna. However, the assemblage of the Northview shale deviates from that of the Chouteau limestone, presumably as a result of different paleoecological conditions, and neither of these stratigraphic units has yielded close counterparts of the two species known from the Fern Glen limestone, probably because that formation is younger. No cephalopods have been described from the Pierson or the Reeds Spring. Altogether we now know the following ammonoids from the Lower Mississippian strata of central and southwestern Missouri:

Chouteau limestone

Imitoceras abundans M. & C., n. sp.
I. discoidale (Smith)
I. jessieae (Miller & Gurley)
I. lentiforme M. & C., n. sp.
Gattendorfia aff. *bransoni* Miller & Youngquist
G. mehli M. & C., n. sp.
Munsteroceras? holmesii (Swallow)
M.? morganense (Swallow)
M. osagense (Swallow)
M.? spp.
Pericyclus? blairi (Miller & Gurley)
Protocanites lyoni (Meek & Worthen)
Prodromites gorbyi (Miller)

Northview shale

Imitoceras brevilobatum M. & C., n. sp.
I. rugilobatum M. & C., n. sp.
Gattendorfia minusculum M. & C., n. sp.
Munsteroceras medium M. & C., n. sp.
M.? spp.
Protocanites gurleyi (Smith)
P. lyoni (Meek & Worthen)

The fact that four genera (*Imitoceras*, *Gattendorfia*, *Munsteroceras* and *Protocanites*) are represented in the Chouteau and the Northview, and especially the occurrence in both of such a diagnostic species as *Protocanites lyoni*, substantiate Branson's belief that the Northview is merely "a phase of the Chouteau." Furthermore, Shepard (1898, p. 86) indicated that locally the Chouteau merges "insensibly" into the Northview. The latter formation, which is confined to the southwestern portion of the state, consists of up to 100 feet of shale and siltstone, and lithologically it resembles the Hannibal. At least locally, it interfingers with limestone beds that are believed to be part of the Chouteau formation. Nevertheless, like Branson, we are inclined to think of the Northview and its fauna as being more or less independent, probably because the lithology is so different from that of the typical Chouteau. (See addendum.)

The Fern Glen limestone proper is confined to central eastern Missouri and southwestern Illinois. It consists of some 50 feet or less of reddish limestone, shale and chert. Although there has been some difference of opinion as to its age, Wilmarth (1938, p. 727) and Weller et al. (1948, p. 100, pl. 2) place it in the lower part of the Osage group or series (in which they also include the Reeds Spring), a procedure now generally followed. The Fern Glen has yielded two goniatites, the holotypes of *Gattendorfia pfefferae* (Miller & Werner) and *G. eshbaughi* (Miller, Downs & Youngquist). Neither of these is close to any of the numerous ammonoids known from the Chouteau, nor to the few forms which have been found in the overlying undoubted Osage and which seem to belong largely if not entirely in the genera *Munsteroceras* and *Beyrichoceras*.

Lower Mississippian ammonoids are rare in Illinois and Iowa. However, *Prodromites gorbyi*, which is locally abundant in the Chouteau limestone of central Missouri, is also known from outcrops of the same formation in central western Illinois and southeastern Iowa. Also, we have a few rather poorly preserved chert goniatites from the Wassonville member of the Hampton formation of the southeastern part of Iowa. The Wassonville limestone, which varies up to some 20 feet in thickness, is generally regarded as being upper Kinderhook in age, and its ammonoids are compatible with that interpretation. They all belong in *Imitoceras* and *Munsteroceras?* but their specific affinities cannot be determined with certainty.

Although there are differences between

the ammonoids that occur in the several Lower Mississippian formations of Missouri, all of them seem to represent more or less a single fauna. That is, the relatively few forms known from the Louisiana and the Hannibal are very close to certain of the Chouteau species and are not even congeneric with any of the goniatites known from the Devonian strata of this hemisphere. The fact that the genera *Gattendorfia*, *Munsteroceras*, *Pericyclus?* and *Prodromites* have been found in the Chouteau and not in the Hannibal or the Louisiana may be due to the relative abundance of ammonoids in that formation, or to a variation in depositional environment, or to a slight difference in age.

A close counterpart of the Chouteau ammonoid fauna has long been known from the type section of the Rockford limestone of Indiana, which "is now submerged due to the construction of a dam across White River at Rockford, and only an occasional goniatite may be found on the gravel bar below the dam" (Campbell, 1946, p. 856). Both this formation and the Chouteau have yielded *Protocanites lyoni* and the unique *Prodromites gorbyi*, as well as a preponderance of *Imitoceras* and *Munsteroceras*. Although *Gattendorfia* and *Pericyclus?* have been found in the Chouteau but not in the Rockford, this is probably of no great significance, for these genera are rare in the Missouri formation. It is perhaps much more noteworthy that the Missouri Kinderhook formations have yielded no forms that are particularly close to *Imitoceras ixion* (Hall) [=? *I. rotatorium* (de Koninck)], *Munsteroceras oweni* (Hall), and *M. parallelum* (Hall); whereas so many representatives of these three species were obtained from the Rockford that study collections of almost every university in the country contain some of them. It seems peculiar that all of the numerous ammonoids collected from the Rockford are referable to only five species. In spite of the fact that three of them are not very close to Chouteau forms, we are of the opinion that the similarities between the faunas of these two formations are more significant than the differences, and that they are therefore approximately contemporaneous. This conclusion is strongly supported by the occurrence of typical representatives of the nautiloid genus *Triboloceras* in both.

In 1862 Winchell described (but did not illustrate) quite a few ammonoids from the Marshall sandstone of Michigan. Through the courtesy of Professor G. M. Ehlers we have been able to restudy a good many of these type specimens; also Professor W. A. Kelly has sent us some additional material from the same formation. This fauna, like that of the Chouteau and the Rockford, contains typical *Protocanites lyoni* as well as numerous representatives of *Imitoceras* and *Munsteroceras* (and *Triboloceras*), and therefore we believe that the strata at these three localities are of about the same age. Dr. Ehlers also loaned us several pyritized specimens (probably the syntypes) of *Goniatites whitei* Winchell of the Coldwater shale, which immediately underlies the Marshall, and they show clearly that this species belongs in the genus *Imitoceras* and that, as is now generally recognized, these beds are almost certainly Lower Mississippian in age, and their stratigraphic position suggests that they are the approximate correlative of the Louisiana and/or Hannibal.

Recently, Miller and Youngquist (1947) recorded the discovery of a related fauna in the Caballero formation of south-central New Mexico, but, unfortunately, it includes only two specimens of ammonoids. One of these is the holotype of *Gattendorfia bransoni* Miller & Youngquist, which seems to be close to one of our congeneric forms from the Chouteau; and the other is related to and possibly identical with *Pericyclus blairi* of the same formation. The Caballero has yielded typical representatives of the nautiloid genera *Welleroceras* and *Triboloceras* which are characteristic of the Chouteau, and the striking similarity of the cephalopods of these two formations indicates that they are not greatly different in age. A related cephalopod fauna has been recorded by Miller, Downs and Youngquist (1949, pp. 606–608, pl. 99, figs. 12–15) from the Redwall limestone of central Arizona.

A few Mississippian goniatites are known from Ohio and Virginia. There has been much difference of opinion as to the age of the strata from which they were collected, but it seems to us that at least the upper part of the Cuyahoga formation (the

"Waverly freestone") of central Ohio and the lower portion of the Price formation of western Virginia are almost certainly to be correlated with the Rockford limestone of Indiana and therefore with the Chouteau limestone of Missouri. This conclusion is based largely on the occurrence of *Protocanites lyoni*, which we believe to be limited to a rather narrow but widespread stratigraphic zone in the United States. Specimens which are identical or very closely similar are also known from Europe, Asia and Australia. Also, the collections of Mount Union College at Alliance, Ohio, contain an undescribed specimen of *Triboloceras* from the Cuyahoga, and those of the State University of Iowa contain a specimen of *Munsteroceras* from the Price (No. 9546).

It has long been recognized that the Kinderhook cephalopod faunas of North America are not similar to any of those known from Britain but are very closely related to those of the Tournaisian of Belgium. In 1940 Delépine published a monograph of the Lower Carboniferous ammonoids of the latter country, and he showed that there are two ammonoid zones in the Tournaisian beds there, both of them in the uppermost part of that series. The older of these is found in the lower half of the Vaulx limestone which has yielded *Protocanites lyoni*, a single fragment of *Imitoceras rotatorium*, and representatives of *Munsteroceras*, *Pericyclus?* and *Acrocanites*. The last genus is not known from America. Its sutures form a large number of lobes and saddles, as do those of *Prodromites*, but the two genera are not closely similar. The younger of the Belgian Tournaisian ammonoid faunas comes from the Calonne limestone, which is believed to occupy a stratigraphic position immediately above the Vaulx. It carries *Imitoceras rotatorium*, three species of *Pericyclus* and two of *Munsteroceras*. These faunas are certainly closely related, and Delépine followed Maillieux and Demanet (1930, table 1) in regarding them as constituting a single formation. The ammonoids of the Chouteau seem to be a little more like those of the Vaulx than those of the Calonne, whereas the Rockford assemblage appears to be about as similar to one as to the other.

Most of the other Lower Carboniferous ammonoids known from Europe seem to be from strata of Viséan age. However, the Schönau sandstone of the southern Swarzwald in southwestern Germany has yielded a form that is either identical with or very closely similar to *Protocanites lyoni*. Presumably, therefore, that formation is upper Tournaisian and the approximate stratigraphic equivalent of the Chouteau and Rockford. Also, the lower Tournaisian and the lower Viséan of Germany have yielded some congeneric forms, for example, *P. supradevonicus* Schindewolf and *P. quadratus* Schindewolf. These are not nearly as close to *P. lyoni* as is *P. algarbiensis* Pruvost of southern Portugal, which is probably upper Tournaisian. As noted by Delépine (1940, p. 25) ammonoid faunas that were believed to be of about the same age have been discovered at two localities in Morocco, but subsequent study (Delépine, 1941, pp. 7–10, 28) has shown that they are really slightly younger, that is, that they are lower Viséan. Also, the form from central European Soviet Russia which Tzweatev (1898, pp. 28–29, pl. 5, fig. 19) referred to "*Brancoceras rotatorium*" is believed by Delépine (1940, p. 28) to be referable to *Imitoceras ornatissimum* (de Koninck) of the lower Viséan.

In 1940 Librovitch described from northern Kazakhstan, in the central Asiatic portion of Soviet Russia, an ammonoid fauna which is probably about the same age as that of the Chouteau. It consists of *Protocanites lyoni* and representatives of *Imitoceras* and *Gattendorfia* as well as two genera not known to occur in North America, *Kazakhstania* and *Karagandoceras*. *Kazakhstania* resembles *Gattendorfia*, but has a much wider umbilicus. *Karagandoceras* is probably related to *Munsteroceras* but has an acute venter, a closed umbilicus, and sutures with a relatively short ventral lobe. Presumably the differences between this Asiatic fauna and those known from America are to be explained by their geographic remoteness, and the fact that they have a characteristic species and two additional genera in common appears quite significant.

The Burindi series of northeastern New South Wales has yielded seven ammonoids which were described by Delépine in 1941 as *Protocanites lyoni*, a closely similar con-

generic species, *Imitoceras* aff. *rotatorium*, *Munsteroceras* sp. ["nearly related to *M. oweni*"], and *Nautellipsites?* sp. The last is a distorted fragment which may belong in *Munsteroceras*. Clearly this assemblage is closely related to those of the Rockford and the Chouteau, to which its similarity is remarkable when one considers the distance separating these localities.

In summary, it seems that the ammonoids of the Chouteau are part of an early Lower Carboniferous fauna that is essentially world-wide in its distribution. The most diagnostic and widespread species of this fauna is *Protocanites lyoni*, nowhere abundant but almost invariably associated with numerous specimens of *Imitoceras* and *Munsteroceras*. Other ubiquitous genera such as *Gattendorfia* and *Pericyclus* occur sporadically in this zone. *Karagandoceras*, *Kazakhstania*, *Acrocanites* and *Prodromites* appear to be relatively limited geographically.

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SYSTEMATIC PALEONTOLOGY

Genus IMITOCERAS Schindewolf, 1923

Genotype: AMMONITES ROTATORIUS de Koninck

There has been much difference of opinion as to the application of the generic terms *Aganides* de Montfort, *Brancoceras* Hyatt, *Prionoceras* Hyatt, *Postprolobites* Wedekind, *Gattendorfia* Schindewolf and *Imitoceras* Schindewolf. Most of the issues are clouded with uncertainties and this fact has accentuated the difficulties.

Aganides was proposed by de Montfort in 1808 (pp. 30–32). He stated that its genotype is the form from the dark fetid limestone near Namur, Belgium, which he had figured and described in 1804 (pp. 253–254, pl. 48, fig. 1). This illustration, a woodcut, is far from satisfactory, and has been interpreted as a nautiloid, possibly *Aturia* or more probably *Aturoidea*, or as a goniatite, especially *Goniatites rotatorius* (de Koninck) or as a form related to *G. striatus* (Sowerby). According to Delépine (1940, p. 36) its age is probably Viséan, early Upper Carboniferous, or possibly Frasnian; and therefore it is almost certainly not *G. rotatorius*, which is characteristic of the Tournaisian. It seems clear that the identity of this form cannot be determined with a reasonable degree of certainty, and, since it must remain the genotype, the genus, although quite valid, is not usable.

When Hyatt (1884, pp. 325–326) established *Brancoceras*, he designated *Goniatites ixion* Hall of the Rockford limestone of Indiana as its type. This name is now generally regarded as a synonym of *G. rotatorius* (de Koninck) from the Tournaisian of Belgium, but this is not certain. Hyatt's name, however, was preoccupied in 1881 by Steinman, who applied it to certain Cretaceous ammonoids.

Prionoceras was also established in 1884 by Hyatt (p. 324), who chose for its genotype *G. divisus* Münster as illustrated by that author in 1843 (pl. 4, figs. 6a–d). The figured specimen is stated to be from near Gattendorf, Bavaria, and presumably it came from the *Gattendorfia*-Stufe, now regarded as early Lower Carboniferous.

Münster's description and illustrations leave much to be desired, but apparently he had some small subglobular specimens with inconspicuous closed umbilici, transverse constrictions forming broad rounded lateral salients and a ventral sinus, and external sutures consisting of three closely spaced, undivided, pointed lobes and a very broad rounded second lateral saddle that extends to the umbilicus. The first lateral saddles were indicated by Münster to be angular, but other authors, like Gümbel (1862, p. 298), have stated that they are rounded. Hyatt recognized that this species is similar to those for which he proposed the name *Brancoceras*, but he thought that the relationship is not close. Furthermore, Schindewolf (1923, pp. 325, 402) has expressed the opinion that these forms should be placed in different families and he suppressed *Prionoceras* as a synonym of *Postprolobites* Wedekind which was not proposed until 1913 and which cannot, therefore, be retained, as it lacks priority. Librovitch (1940, pp. 227–229) has called attention to these facts and has questioned the taxonomic value of the characters on which Schindewolf relied, that is, differences in the growth-lines, constrictions, and presumed mode of origin of the sutural elements. We are not able to check these conclusions from the specimens now available to us, but it seems quite possible that detailed studies of well preserved material will show that the name *Prionoceras* should be applied to many of the Lower Carboniferous ammonoids. In 1920 Buckman, unaware of Hyatt's earlier use of the name *Prionoceras*, employed it for a genus of Jurassic ammonites, but he later recognized the lack of priority of his name and substituted *Prionodoceras* for it.

The genotype of *Postprolobites* is *P. yakowlewi* Wedekind of the German Upper Devonian. As is now generally recognized it is similar to and presumably congeneric with the type species of *Prionoceras*, which has priority.

Goniatites subinvolutus Münster of the Lower Carboniferous of Gattendorf, Germany, is the genotype of *Gattendorfia* Schindewolf, 1920. It has an open umbilicus and sutures which are essentially like those of the forms just mentioned except that the umbilical lobe centers outside the umbilical seam rather than on it.

In 1923 Schindewolf (pp. 325–328) pointed out most of the facts just mentioned and established a genus, *Imitoceras*, for which he later (1926, p. 70) named a genotype, *Ammonites rotatorius* de Koninck from the Tournaisian of Belgium. This generic name has come to be rather widely used.

Librovitch (1940, p. 226) has concluded that the "main difference" between *Gattendorfia* and such genera as *Imitoceras* and *Prionoceras* is that its umbilical lobe centers outside rather than on the umbilical seam, and a "second difference" is that the umbilicus is open rather than closed. We are inclined to believe that the latter is of more importance than the former. Furthermore, it seems to us that the taxonomic significance of the distinguishing characteristics of typical *Prionoceras* and typical *Imitoceras* needs to be assessed carefully in light of the conclusions expressed by Librovitch (1940, p. 227), who believed that Schindewolf and Wedekind evaluated the differences too highly. Meanwhile, we propose to use *Imitoceras* in a rather broad sense for ammonoids with closed umbilici and sutures which consist of eight undivided lobes separated by rounded saddles. At the same time, *Gattendorfia* will be applied to forms with similar sutures but open umbilici.

The genotype of *Paralytoceras* Frech, *Clymenia crispa* Tietze of the Upper Devonian of Germany, is so incompletely known that its affinities are very uncertain. According to Frech (1902, pp. 83–84, pl. 4, fig. 14) the general form of its conch and the portions of its sutures that have been observed are similar to those of the type species of *Gattendorfia*, a conclusion which we are not able to confirm or reject. Until more is known about Tietze's species, it is doubtful if congeneric forms can be recognized with reasonable certainty or the relationships of the genus determined satisfactorily.

In 1940 (pp. 67–68, 243–245) Librovitch proposed the name *Kazakhstania* for two species from the early Lower Carboniferous of the central Asiatic portion of Soviet Russia. He regarded these as constituting

a subgenus of *Gattendorfia*, but in both the conch is only slightly involute and therefore the general form is not very similar to that of typical *Gattendorfia*. It seems to us that Librovitch's species are probably related to *Gattendorfia*, but that they differ sufficiently from its type to be regarded as generically distinct.

Imitoceras, as interpreted by us, is widely distributed. In the eastern hemisphere it occurs in the Upper Devonian, the Tournaisian and the Viséan. In America it has not been found below the Kinderhook, where it is fairly abundant. Two of our basal Osage (Fern Glen) species have been referred to this genus, but in them the umbilicus is open. They probably should be placed in *Gattendorfia*, although in both the umbilical lobe centers on the umbilical seam rather than outside it, as in the type of that genus. No comparable forms are known from younger Mississippian strata, but the Pennsylvanian of Missouri, Kansas, Texas, and probably Oklahoma, has yielded some small specimens that seem to possess all of the diagnostic characters of *Imitoceras*. Plummer and Scott (1937, p. 350) proposed the generic name *Neoaganides* for these, but the differences between them and certain of the much older representatives of *Imitoceras* do not seem to be of more than specific rank. Also, one similar small form has long been known from the Middle Permian of Sicily. These Pennsylvanian and Permian species may, of course, be homeomorphs of typical *Imitoceras*.

IMITOCERAS ABUNDANS Miller & Collinson, n. sp.
Plate 68, figures 1–8; plate 69, figures 7, 8

The Chouteau limestone of Missouri has yielded about 35 specimens that seem to represent an unnamed species of *Imitoceras* and we have one individual from the Hannibal shale of the same state and three from the Wassonville limestone of southeastern Iowa that are probably conspecific. All of these are internal molds, but only a few of them reveal their sutures. The one represented by figures 4 and 5 on plate 68 seems to be the best of the lot, and we designate it the holotype.

In this species the conch is discoidal in shape and attains a diameter of at least 30 mm. The whorls are flattened laterally and rounded ventrally. Where they are about 16 mm. high, their width is about 11 mm. However, the specimen illustrated by figure 1 on plate 68 shows that the inner volutions are relatively wide, and figures 7 and 8 on the same plate represent an individual which appears to correspond closely to the penultimate volution of the specimen illustrated by figures 1–3 on that plate. The umbilicus is small, inconspicuous, and closed.

The internal mold bears rounded transverse constrictions, of which there are three or four to the volution. These are almost straight and directly transverse on the lateral zones of the conch, but they curve slightly apicad as they cross the ventral side. On well preserved internal molds there are rather prominent traces of the increments of growth, and these form very slight lateral sinuses and rather deep rounded ventral ones.

As indicated by text-figure 1B, each mature external suture consists of a deep blunt ventral lobe and on either side of it a U-shaped first lateral saddle, a V-shaped but narrowly rounded first lateral lobe, and a relatively broad rounded second lateral saddle which extends to the umbilicus. Apparently there is a small umbilical lobe, and, as shown by figure 7 on plate 68, the internal sutures form three narrow lobes grouped together rather closely near the dorsum. The internal first lateral saddles seem to be U-shaped, whereas the second lateral ones are very broad and are broadly rounded.

Remarks.—This species is the most abundant ammonoid in the limestone phase of the Chouteau. It seems to be represented also in the Wassonville limestone of southeastern Iowa, from which we have three specimens (pl. 69, figs. 7, 8) that unfortunately do not reveal the shape of the sutures. The specimen represented by figure 6 on plate 68 is the only ammonoid known from the Hannibal shale. Although its preservation leaves much to be desired, all of its characters that can be determined seem to compare favorably with those of the Chouteau types.

The congeneric forms which occur in direct association with this species can be

distinguished from it quite readily. In *I. discoidale* (Smith) and *I. jessieae* (Miller & Gurley) there are no constrictions on the internal mold, and in the latter the conch is relatively wide. *I. compressum* (Moore) of the Louisiana limestone is quite similar in size, shape, and proportions of the conch, but the details of at least its external sutures are different. Its ventral lobe is more strongly constricted proximally, and this lobe and the lateral ones are more sharply pointed.

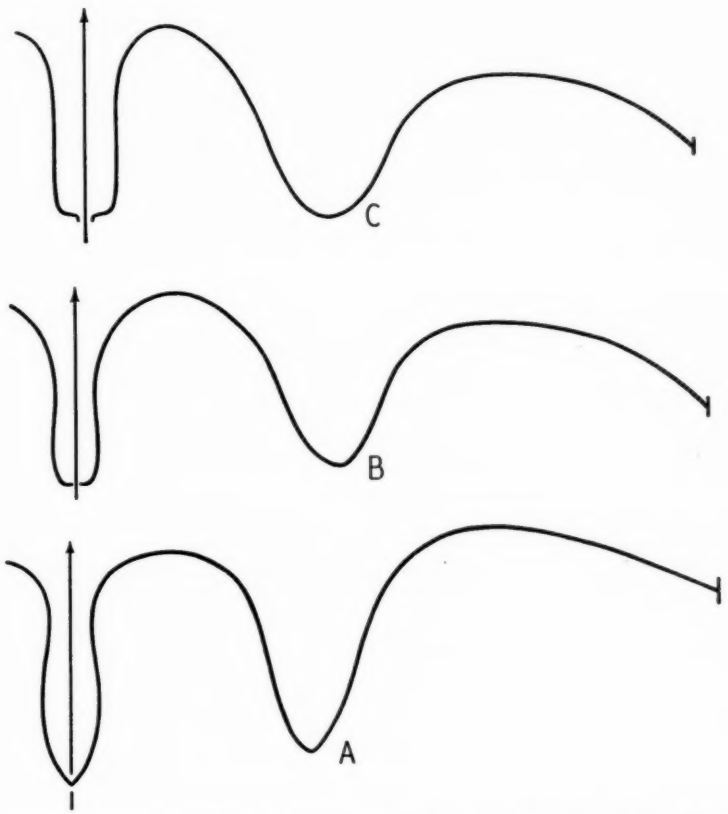

FIG. 1—Diagrammatic representations of external sutures. *A*, The adoral suture of the holotype of *Imitoceras compressum*, where conch is about 14 mm. high, ×3; *B*, antepenultimate suture of the holotype of *I. abundans*, where the height of conch measures about 7½ mm., ×10; and *C*, the adoral suture of a specimen of *I. discoidale* (Smith), (State Univ. Iowa, 6790) from the Chouteau limestone near Sedalia, Missouri, where the conch is about 14 mm. high, ×6.

Occurrence—Chouteau limestone of Missouri at the following localities: (1) County farm about 1½ miles north of Sedalia (14 specimens) and other unrecorded localities in Pettis County; (2) roadside about 1 mile south of Clifton City and along Creagan Creek near that town, Cooper County (holotype; pl. 68, figs. 1–3, etc.); (3) near Providence, 6 miles southeast of Ashland, and one-third mile east of Friendship Church, all in Boone County; (4) 3½ miles northeast of Williamsburg (10 feet above base of formation there), Callaway County (one specimen); and (5) Snake Den section near Newark, Knox County (one specimen). A specimen which may be conspecific was found in the Hannibal shale about 8 miles southwest of Monroe City, Monroe County, Missouri, and three others came from the Wassonville limestone in or near the Wassonville quarry of southeastern Iowa. (See addendum.)

Types.—University of Missouri, 1038, 1142, 3909 (pl. 68, fig. 6), 3920 (pl. 68, figs. 7, 8), 3931, 3950 (pl. 68, figs. 1–3), 3951, 3963, 3967, 3979, 4359; and John Britts Owen Collection at State University of Iowa, 6792 (pl. 69, figs. 7, 8), 6793, 6794 (14 specimens), 6795, 6796, 13906, 13920 (holotype), 13970–13972.

IMITOCERAS BREVILOBATUM Miller & Collinson, n. sp.
Plate 68, figures 18, 19

The late Professor E. B. Branson, in company with Mr. Philip Morey, found at King Butte an incomplete though well preserved limonitic internal mold that belongs in *Imitoceras* but is not referable to any previously described species. Its name is descriptive of its most distinctive characteristic, which seems to be the short ventral lobe of its sutures.

This specimen represents about a third of a volution of a phragmacone and comparable portions of the inner whorls which do not appear to be well preserved. Its maximum overall measurement is about 9 mm., and we estimate that this part of the conch was some 10 mm. in diameter. Near its adoral end, the specimen attains a height and width of conch of about 5 mm. and 7 mm., respectively.

The umbilicus is not large but rather deep. Probably it was closed and there is a small subconical prominence in the center (only one side of the specimen is preserved). The umbilical shoulders are rounded and not very definite.

The surface of the internal mold bears a few deep, rounded, transverse constrictions which are slightly sinuous, forming broad rounded lateral and ventral sinuses. No traces of the growth lines or other markings except the sutures can be discerned.

The shape of the internal sutures is not revealed by the holotype. Each external suture consists of a moderately short, almost straight-sided, bluntly pointed ventral lobe and on either side a more or less U-shaped somewhat asymmetrical first lateral saddle, an asymmetrically V-shaped pointed first lateral lobe, and a low broad rounded second lateral saddle which extends to the umbilicus (see text-fig. 2A). Much of an external suture can be seen near the junction of the two outer volutions and there the ventral lobe seems to be relatively long, but distinctly shorter than the lateral lobes.

Remarks.—No species are known, at least from America, that are very close to this one. The form described below as *Gattendorfia minusculum* is superficially similar, but it has an open umbilicus.

Occurrence.—Northview shale at King Butte (NE¼ NE¼ sec. 27, T. 31 N., R. 22 W.), about 15 miles north of Springfield, Greene County, Missouri.

Holotype.—University of Missouri, 4484.

IMITOCERAS COMPRESSUM (Moore)
Plate 69, figures 11, 12

Aganides compressus MOORE, 1928, Missouri Bur. Geology and Mines, 2d ser., vol. 21, p. 283, pl. 13, figs. 7, 8; WILLIAMS, 1943, U. S. Geol. Survey Prof. Paper 203, pp. 33, 108, pl. 9, figs. 51–54.

The single specimen on which Moore based this species is a moderately well preserved though somewhat fragmental internal mold consisting of light buff fine-grained limestone. It is discoidal in shape and, although not complete adorally, has a maximum diameter of about 34 mm. Most of the outer volution is non-septate and therefore represents the living chamber. Near mid-length this volution is about 16 mm. high, and has an estimated width of about 11 mm. The umbilicus is small, closed, and inconspicuous, and the umbilical shoulders are rounded and indefinite.

The surface of the internal mold bears a few rounded transverse constrictions. These are essentially straight and directly transverse on the lateral zones, but they form rounded ventral sinuses. Traces of the growth lines are almost parallel to these constrictions but seem to form slightly deeper ventral sinuses.

Each external suture consists of an undivided, pointed spatulate ventral lobe, whose proximal portion is considerably constricted, and on either side of it a U-shaped first lateral saddle, a pointed V-shaped first lateral lobe nearly as deep as the ventral lobe, and a low, broadly rounded second lateral saddle extending to the umbilicus (see text-fig. 1A). The internal sutures are not known.

Remarks.—Both Moore and Williams noted that this form has very much the

same proportions as *I. discoidale* (Smith) of the Chouteau limestone "but is chiefly distinguished by the character of the septal suture." Unfortunately, only part of the external suture is revealed by the holotype of the Chouteau form, and therefore satisfactory comparisons are not possible. The two species can be differentiated readily, however, by the fact that there are sinuous transverse constrictions on *I. compressum* but not on *I. discoidale*. *I. abundans* of the Chouteau has similar proportions and constrictions, but the ventral and lateral lobes of its sutures are less sharply pointed, and the flanks of the ventral lobe are less converging proximally (cf. text-figs. 1A and 1B).

Occurrence.—The holotype came from the Louisiana limestone at Hamburg, Calhoun County, Illinois. Williams stated: "A fragmentary mold from the Louisiana limestone at Louisiana, Mo., has about the same size and outline as *A.* [*I.*] *compressus*, but it is too poorly preserved for satisfactory determination." He gave no additional information regarding this specimen, and indicated that it is "very tentatively identified." We have not seen it.

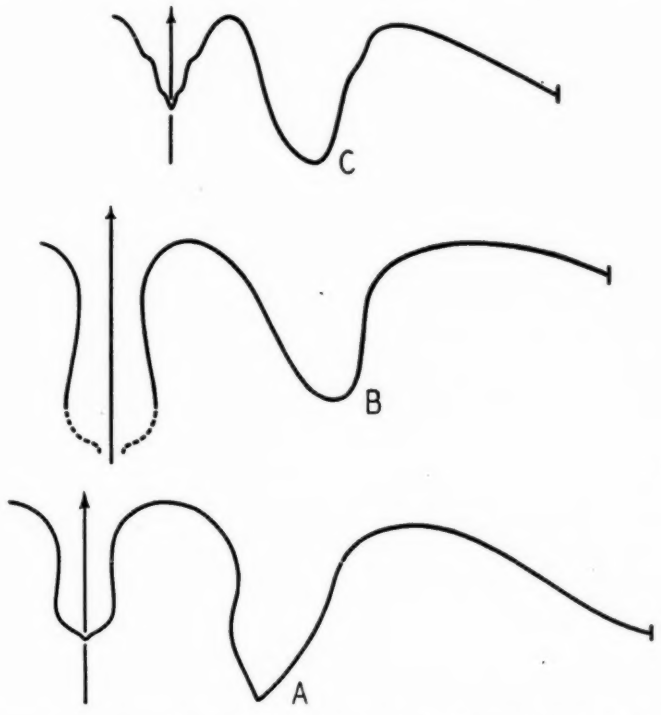

FIG. 2—Diagrammatic representations of external sutures. *A*, The mid-portion of the preserved part of outer volution of holotype of *Imitoceras brevilobatum*, where the conch is about 5 mm. high and 6 mm. wide, ×10; *B*, the third from the last suture of the holotype of *I. jessieae*, where the height of conch is about 11 mm. and the width is estimated to be about 9 mm., ×5½; and *C*, the mid-portion of the adoral half of the outer volution of the holotype of *I. rugilobatum*, where the overall diameter of the specimen is about 6¼ mm., ×12½.

Holotype.—Walker Museum at University of Chicago, 32117.

IMITOCERAS DISCOIDALE (Smith)
Plate 68, figures 9–11

Aganides discoidalis SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 13, 114–115, 145, pl. 24, figs. 5–7; MOORE, 1928, Missouri Bur. Geology and Mines, 2d ser., vol. 21, p. 283; WILLIAMS, 1943, U. S. Geol. Survey Prof. Paper 203, p. 108.

This species is one of the more abundant goniatites in the limestone portions of the

Chouteau formation, which has yielded about 20 representatives. Also, we are placing in it a single individual from the Wassonville limestone of southeastern Iowa. Most of these specimens do not retain their sutures, and their affinities may, therefore, be somewhat questionable.

The holotype is a moderately well preserved internal mold of discoidal shape and about 31 mm. in diameter. It is not complete adorally, but almost all of its outer volution is non-septate and therefore represents living chamber. The whorls are rounded ventrally and flattened laterally, and their lateral zones, although very broadly rounded, are almost parallel. Near the adoral end this specimen is about 18 mm. high and 11 mm. wide. The umbilicus is closed, very small and inconspicuous.

The surface of the holotype bears fairly distinct traces of the growth lines. These are almost straight and directly transverse on the lateral zones but form rather deep rounded ventral sinuses.

The single suture that is visible on this specimen does not reveal the shape of the ventral lobe, but the first lateral saddles are rounded and more or less U-shaped, the first lateral lobes are V-shaped, and the second lateral saddles, which extend to the umbilicus, are relatively broad and shallow, and they are broadly rounded. On the side of this specimen which we do not illustrate, the first lateral lobe is considerably deeper than its counterpart shown by figure 10 on plate 68, and also it is subangular rather than narrowly rounded.

Most of the specimens that we refer to this species are of about the same general size as the holotype or a little smaller. The one represented by figure 9 on plate 68 is about 45 mm. in diameter. This individual retains its test, and, as might be expected, the transverse markings on it are much more prominent than they are on the internal mold. They are almost like low ribs on the ventrolateral and ventral zones. On the lateral zones of this specimen very faint longitudinal ribs can be discerned.

The diagrammatic representation of a suture shown as text-figure 1C is based on an internal mold of about the same size as the holotype, but only the adoral quarter-volution of it represents the living chamber. This specimen is slightly distorted, but it reveals the shape of the sutures quite satisfactorily.

Remarks.—This species resembles the associated *I. abundans*, but the latter bears rather prominent transverse constrictions on the internal mold. *I. compressum* of the Louisiana limestone is also similar, but can be distinguished by the more sharply pointed ventral and lateral lobes and the flanks of the ventral lobe which are not essentially parallel (cf. text-figures 1A and 1C).

Occurrence.—Chouteau limestone of Missouri at the following localities: (1) just below bridge across Osage River west of

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EXPLANATION OF PLATE 68

FIGS. *1–8—Imitoceras abundans* M. & C., n. sp. *1–3*, A fully mature specimen which exposes an inner volution, ×1½; *4, 5*, the holotype, ×2; *6*, a specimen compared with this species, ×1½; *7, 8*, an immature individual, ×3. From the Chouteau limestone; *1–5*, near Clifton City, *7, 8*, from Ashland, Missouri; and *6*, from the Hannibal shale about 8 miles southwest of Monroe City, Missouri. (p. 460)

9–11—Imitoceras discoidale (Smith). *9*, A large testiferous specimen; *10, 11*, the holotype. All ×1; from the Chouteau limestone; *9*, near Hinton, *10, 11*, from an unrecorded locality in Pettis County, Missouri. (p. 463)

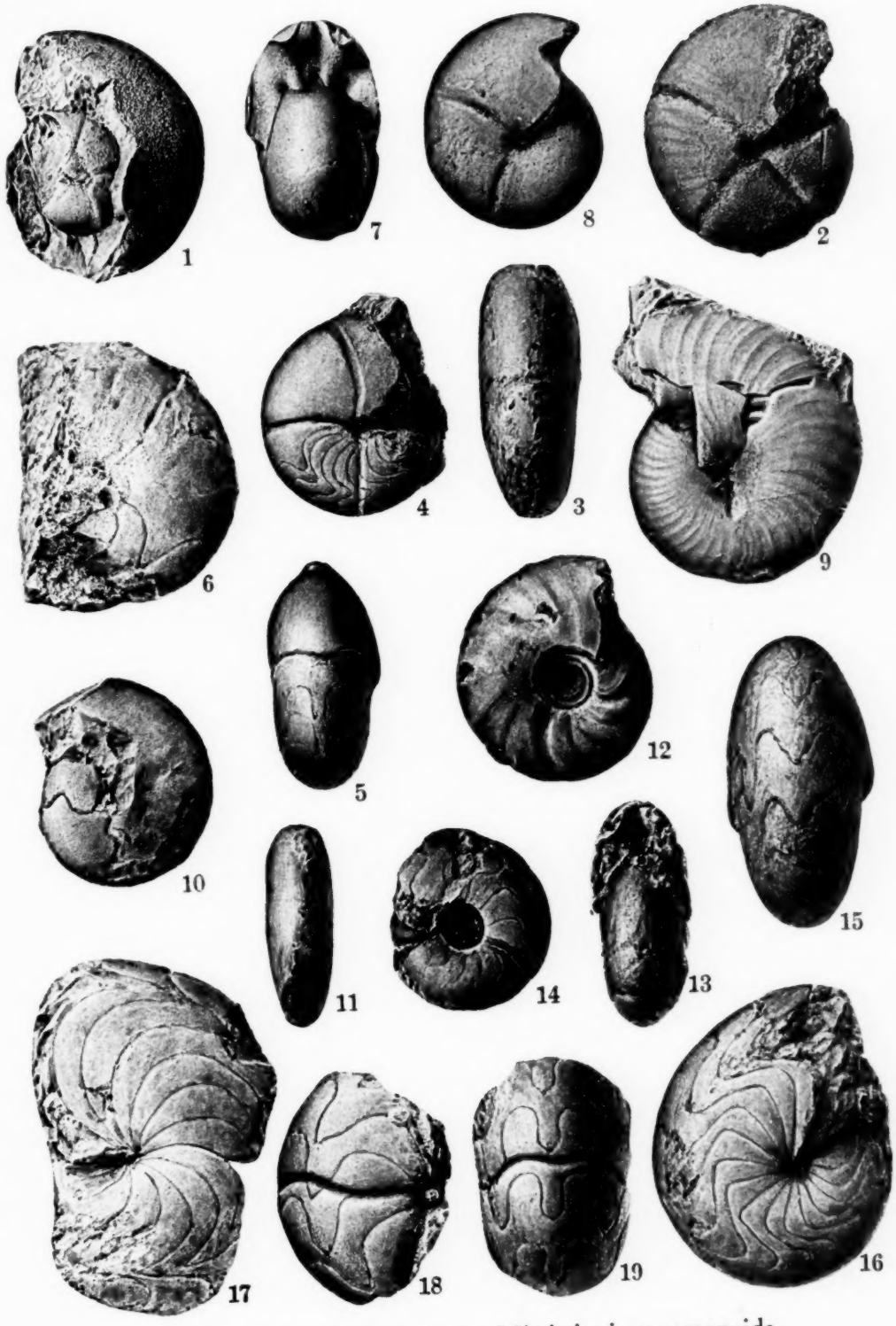
12, 13—Munsteroceras? sp. A specimen that does not reveal the sutures, from the Northview shale at King Butte, about 15 miles north of Springfield, Missouri; ×1½. (p. 474)

14—Gattendorfia minusculum M. & C., n. sp. A paratype, from the same zone and locality as *12, 13;* ×3. (p. 470)

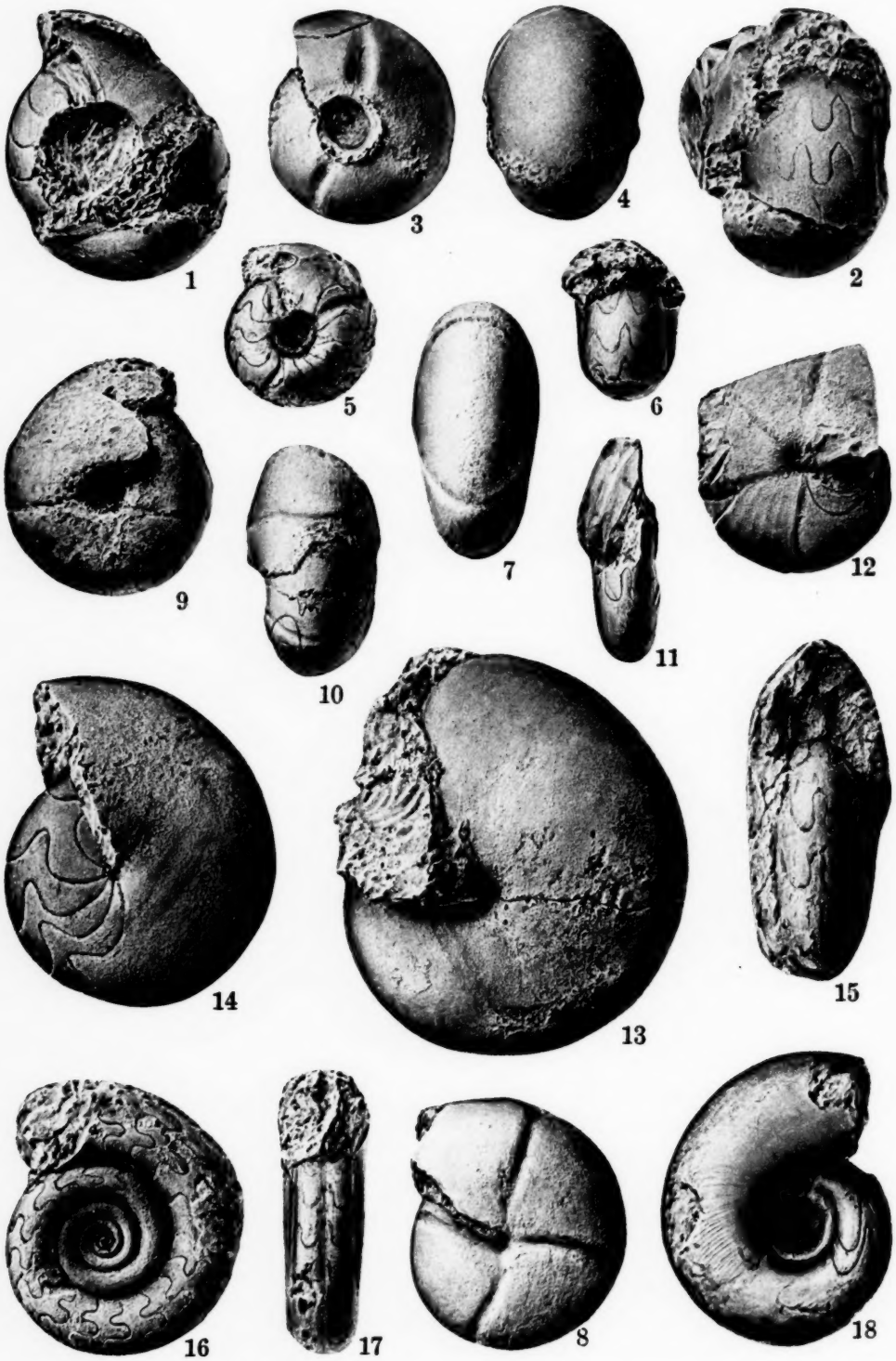
15, 16—Imitoceras rugilobatum M. & C., n. sp. The holotype, from the same zone and locality as *12, 13;* ×6. (p. 467)

17—Imitoceras lentiforme M. & C., n. sp. The holotype, from the Chouteau limestone about 1½ miles north of Danville, Missouri, ×1 (p. 466)

18, 19—Imitoceras brevilobatum M. & C., n. sp. The holotype, from the same zone and locality as *12, 13;* ×4. (p. 462)



Miller and Collinson, Lower Mississippian ammonoids



Miller and Collinson, Lower Mississippian ammonoids

Osceola in St. Clair County; (2) east bluff of Weaubleau Creek on Darnell farm in Hickory County; (3) top of hill about 1 mile north of Warsaw in Benton County; (4) near Sedalia, 1½ and 3½ miles north of that city, on Shepard farm ½ mile north of Georgetown, and other unrecorded localities (one of which yielded the holotype), all in Pettis County; (5) Chouteau Springs in Cooper County (16–20 feet below top of formation); (6) 3½ miles north of Browns Station and 3 miles northeast of Hinton, both in Boone County; (7) 3½ miles northeast of Williamsburg in Callaway County (10 feet above base of formation); and SW¼ sec. 2, T. 46 N., R. 5 W., in Warren County. Also the Wassonville limestone at some unrecorded locality in southeastern Iowa has yielded a specimen which seems to be referable to this species but is only moderately well preserved.

Figured specimens.—Walker Museum at University of Chicago, 8601 (holotype); and John Britts Owen Collection at State University of Iowa, 6790 (text-fig. 1C), 13902 (pl. 68, fig. 9). The Wassonville specimen is also at the latter institution, where it is numbered 6791.

IMITOCERAS JESSIEAE (Miller & Gurley)
Plate 69, figures 13–15

Goniatites jessieae MILLER & GURLEY, 1896, Illinois State Mus. Nat. History Bull. 11, pp. 46–47, pl. 5, figs. 18–20.
Aganides jessieae HAUG, 1898, Soc. géol. France Mém. Paléont., t..7, no. 18, pp. 39, 62; SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 13, 115, pl. 17, figs. 18–20.
Tornoceras Jessie CLARKE, 1899, New York State Geologist Ann. Rept. 16, p. 110. (Also issued as New York State Mus. Ann. Rept. 50, vol. 2.)
Imitoceras jessiae LIBROVITCH, 1940, Paleont. U.S.S.R., vol. 4, pt. 9, fasc. 1, pp. 18, 207, 318.

The figured type specimen of this species is a rather well preserved internal mold which is somewhat crushed, so that one side of it cannot be removed from the matrix. Its maximum diameter is about 39 mm. The adoral quarter-volution has been broken away from the rest of the specimen, revealing the sutures. The length of the preserved portion of the living chamber is slightly less than one full volution.

The conch is sublenticular in shape, as its whorls are narrowly rounded ventrally and their lateral zones are broadly rounded and converged ventrad. Near the adoral end of the figured specimen the conch is about 24 mm. high, and its corresponding maximum width, which is greatest near the umbilical shoulders, is estimated to be about 16 mm. The umbilicus is small, inconspicuous and closed. The umbilical shoulders are rounded and indefinite. Faint traces of the growth lines on the adoral portion of the specimen form a broad rounded lateral salient on each side of the conch and a deep, narrowly rounded ventral sinus.

The two adoral camerae of the original figured type are distinctly shorter than the preceding ones, indicating that this specimen represents a fully mature individual.

EXPLANATION OF PLATE 69

FIGS. *1, 2*—*Gattendorfia* aff. *bransoni* Miller & Youngquist. A crushed fragmental specimen from the Chouteau limestone about 1 mile south of Clifton City, Missouri; ×2. (p. 468)

3, 4—*Munsteroceras?* sp. A specimen of uncertain affinities, from the Wassonville limestone at Kalona, Iowa; ×3. (p. 474)

5, 6—*Gattendorfia minusculum* M. & C., n. sp. The holotype, from the Northview shale at King Butte, about 15 miles north of Springfield, Missouri; ×3. (p. 470)

7, 8—*Imitoceras abundans* M. & C.? A specimen which does not reveal the sutures, from the Wassonville limestone of southeastern Iowa; ×2. (p. 460)

9, 10—*Munsteroceras medium* M. & C., n. sp. The holotype, from the same zone and locality as *5, 6*; ×2. (p. 472)

11, 12—*Imitoceras compressum* (Moore). The holotype, from the Louisiana limestone at Hamburg, Illinois; ×1. (p. 462)

13–15—*Imitoceras jessieae* (Miller & Gurley). *13*, The holotype; *14, 15*, all but the adoral quarter of the outer volution of the same individual. From the Chouteau limestone near Sedalia, Missouri; ×1½. (p. 465)

16, 17—*Protocanites gurleyi* (Smith). The holotype, from the Northview shale near Cedar Gap, Missouri; ×2½. (p. 478)

18—*Gattendorfia subinvoluta* Münster. The holotype of the type species, from the basal Lower Carboniferous near Gattendorf, Germany; slightly less than ×1. (After Frech.) (p. 467)

As shown by text-figure 2B, each external suture consists of a deep narrow ventral lobe and on either side of it a U-shaped first lateral saddle, a V-shaped but narrowly rounded first lateral lobe, and a broad rounded lateral saddle which extends to the umbilicus. The preservation of this specimen is such that the adapical portion of the ventral lobe cannot be determined with certainty in any of the sutures exposed.

Remarks.—Messrs. Kenneth Caster and Donald Baird of the University of Cincinnati have permitted us to study all three of the original type specimens of this species. Only one, the figured individual, reveals the nature of the sutures, and it is here designated the lectotype. The larger of the remaining two shows that the conch attained a maximum diameter of at least 56 mm. The other is so poorly preserved and distorted that its affinities cannot be ascertained.

The collections available to us contain many specimens from the Chouteau of Missouri that probably belong in this species. However, most of them leave much to be desired, and they do not reveal the shape of their sutures.

This species seems to be very close to several congeneric forms that occur in the same formation, but can be distinguished, as its growth lines are not prominent and they form lateral salients, there are no constrictions on the internal mold, and the umbilicus is small and inconspicuous.

Occurrence.—The original types came from the Chouteau limestone "near" Sedalia, Pettis County, Missouri. Specimens which appear to us to be conspecific (but few of which retain sutures) have been collected from the same formation at the following localities, all in Missouri: 3½ miles and 5 miles north of Sedalia; Darnell farm on east bluff of Weaubleau Creek, near Weaubleau, Hickory County; 3 miles east of Easley, Boone County; near Providence, Boone County; and on the Middle Fabius River about 6 miles north of La Belle, Lewis County.

Repositories.—University of Cincinnati, 3896 (holotype), 3897 (paratypes); University of Missouri, 3932 (three specimens), 3955 (one specimen), 3968 (two specimens), 4689 (one specimen), and one unnumbered specimen; John Britts Owen Collection at State University of Iowa, 6790 (two specimens), 13904 (one specimen), 13908 (one specimen), 13909 (two specimens), 13912 (one specimen); and private collection of J. B. Dyer of La Belle, Missouri (three specimens).

IMITOCERAS LENTIFORME Miller & Collinson, n. sp.
Plate 68, figure 17

The paleontological collections of the University of Missouri contain a unique internal mold that is much thinner than any of the other congeneric forms known, at least from America. It is septate throughout and has a diameter of about 54 mm. and a maximum width of about 9 mm. somewhat dorsad of the mid-height. The corresponding height of conch measures about 31 mm. As indicated by text-figure 3A, the conch is lenticular, for its ventral zone is almost angular whereas its lateral ones are very broadly rounded and seem almost flat. The umbilicus is very small, inconspicuous and closed. Umbilical shoulders hardly exist.

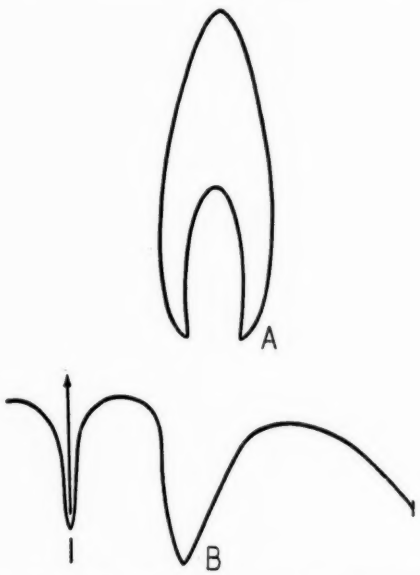


FIG. 3—Diagrammatic cross-section, *A*, and representation of an external suture, *B*, of *Imitoceras lenticulare*, ×1½ and ×2, respectively. The former is based on the adoral part of the holotype, the latter on the mid-portion of the outer volution of the same specimen.

No traces of surface markings can be discerned on the holotype.

The camerae are short, and there are about 15 of them in the outer volution. The lateral lobes of the sutures are slightly telescoped and almost in contact. Each external suture forms a moderately deep, very narrow ventral lobe and on either side of it a U-shaped first lateral saddle, a V-shaped first lateral lobe, and a relatively low and broad rounded second lateral saddle which extends to the umbilicus (text-fig. 3B).

Remarks.—This species can be differentiated readily, by the shape of its conch, from all of the representatives of *Imitoceras* known to us. Its most distinctive features seem to be the narrowness of its whorls and the almost angular ventral zone.

Occurrence.—Chouteau limestone, about 1½ miles north of Danville (NE ¼ sec. 13, T. 48 N., R. 6 W.), Montgomery County, Missouri.

Holotype.—University of Missouri, 3912.

IMITOCERAS RUGILOBATUM Miller & Collinson, n. sp.
Plate 68, figures 15, 16

The sutures of a small specimen in the collections under consideration differ from those of all similar forms in having the flanks of the ventral lobe rather strongly sinuous. This can be seen quite clearly on seven or eight adjacent sutures and is not merely a matter of preservation, interpretation or adolescence. We propose a specific name for this form with some hesitation.

The specimen is a discoidal limonitic internal mold about 8 mm. in diameter, septate throughout. The maximum height and width of the preserved portion are about 5 mm. and 3½ mm., respectively. The whorls are rather narrowly rounded ventrally and considerably flattened laterally. The umbilicus is small but quite distinct; it was probably closed by the test. The umbilical shoulders are rounded and rather indefinite.

Faint traces of growth lines on this specimen form shallow rounded ventral and lateral sinuses separated by similar ventrolateral and dorsolateral salients.

The shape of the external sutures is indicated by text-figure 2C. Each consists of a pointed V-shaped ventral lobe, with sinuous flanks, and on either side of it a narrowly rounded first lateral saddle, a similar but much deeper first lateral lobe, the dorsal flank of which is slightly but distinctly sinuous, and a broad asymmetrical second lateral saddle which extends to the umbilicus.

Remarks.—Except for the sinuosity of the flanks of the lobes of its external sutures, this species is typical of *Imitoceras*. No forms are known to us that are sufficiently similar to justify detailed comparisons, but certain features of the sutures are somewhat similar to those of *Paralytoceras crispum* (Tietze) of the Upper Devonian of Germany as represented by Schindewolf (1920, p. 123, fig. 1E).

Occurrence.—Northview shale at King Butte (NE ¼ NE ¼ sec. 27, T. 31 N., R. 22 W.), about 15 miles north of Springfield, Greene County, Missouri.

Holotype.—University of Missouri, 4485.

Genus GATTENDORFIA Schindewolf, 1920
Genotype: GONIATITES SUBINVOLUTUS Münster

The type species of this genus (see text-fig. 4 and pl. 69, fig. 18) is from the basal Lower Carboniferous of east central Germany. Possibly it occurs also in the central

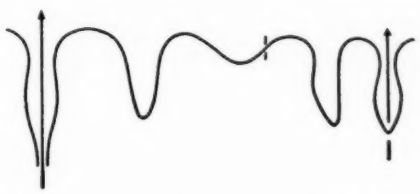


FIG. 4—Diagrammatic representation of a suture of the genotype, *Gattendorfia subinvoluta* from the basal Lower Carboniferous of Germany, presumably ×1½. Adapted from Schindewolf.

Asiatic portion of Soviet Russia. It has a subglobular conch, a rather large open umbilicus, and sutures that consist of eight undivided lobes separated by an equal number of rounded saddles. The umbilical lobes are the only ones that are not more or less pointed, and they are relatively low and center well outside the umbilical seams. Librovitch (1940, p. 226) has stated that

this last character is the "main difference" between *Gattendorfia* and *Imitoceras*, in which the umbilical lobes typically center on the umbilical seams. The position of the umbilical lobe has been found to vary in such Pennsylvanian genera as *Pseudoparalegoceras* (see Miller and Furnish, 1940, p. 529), however; and we are inclined to attribute more taxonomic significance to the rather large and open umbilicus in the genotype of *Gattendorfia*, which in the genotype of *Imitoceras* is small, inconspicuous and closed. Librovitch noted that the umbilicus is not the same in these two type species and regarded this as a "second difference." Schindewolf seems to have considered the umbilicus less important, and he placed these two genera in different families because of variations in their growth lines and transverse constrictions. Most of our specimens are internal molds which do not retain traces of the growth lines and many of them have no constrictions. We find it difficult, if not impossible, to apply the criteria on which Schindewolf relied.

It seems best to refer our forms with relatively simple sutures, whose ventral lobes are undivided, to *Imitoceras* and *Gattendorfia*, and to differentiate these genera on the character of the umbilicus, which is closed in the former and open in the latter. We recognize, however, that this procedure, like all of the others, has its disadvantages, for there are more or less gradational forms.

Gattendorfia, as we are interpreting it, seems to be widespread in the early Lower Carboniferous of both this country and Eurasia. In the eastern hemisphere it is also represented in the Devonian, but no American species are known from that system.

GATTENDORFIA aff. BRANSONI Miller & Youngquist
Plate 69, figures 1, 2

Gattendorfia sp. MILLER & YOUNGQUIST, 1947, Jour. Paleontology, vol. 21, p. 117.

The paleontological collections of the University of Missouri contain a crushed fragmental specimen that appears to resemble the holotype of *G. bransoni*, except that it is considerably smaller. Because of this, detailed measurements have little significance. The adoral two-thirds of the outer volution are non-septate and presumably represent the living chamber. The whorls are depressed and broadly rounded ventrally (see text-fig. 5A). In the adapical third of the outer volution, where the conch is about 9 mm. wide, its height is estimated to be a little more than 3 mm.

The umbilicus is moderately large, and its diameter is equal to about two-fifths that of the entire specimen. The umbilical shoulders are very abrupt, and the umbilical walls seem to be steep.

The surface of the internal mold bears low, very inconspicuous and easily overlooked rounded ribs which appear to be directly transverse to the long axis of the conch and extend from one umbilical shoulder to the other. The intermediate grooves are of about the same size and magnitude as the ribs.

Each external suture consists of a rather long, undivided spatulate ventral lobe and on either side of it a U-shaped first lateral saddle, a first lateral lobe that is intermediate between V-shaped and spatulate, and a wide, broadly rounded second lateral saddle that extends to the umbilical shoulder (see text-fig. 5B). The nature of the sutures on the umbilical wall and internally is not known.

Remarks.—Direct comparison of this specimen with the holotype of *G. bransoni* has led us to conclude that these individuals are similar but probably not conspecific. Both leave much to be desired, but the Missouri individual seems to have a relatively large umbilicus, and the second lateral saddle of its sutures seems to be more broadly rounded. Neither specimen is very close to the form for which we are proposing the name *G. mehli* nor to the type species of the genus, *G. subinvoluta*. In the genotype the umbilicus is relatively small, and the sutures, particularly the second lateral saddles, are markedly different.

Occurrence.—Chouteau limestone by roadside about 1 mile south of Clifton City, Cooper County, Missouri. The holotype of *G. bransoni* is from the Caballero formation of south central New Mexico.

Figured specimen.—John Britts Owen Collection at State University of Iowa, 8051.

GATTENDORFIA MEHLI Miller & Collinson, n. sp.
Plate 70, figure 11

This species is based on a single internal mold which is slightly distorted and freed from the matrix on one side only. The specimen is completely septate and therefore represents only phragmacone. Except in the adoral quarter-volution, its borders are not very definite, and it seems to grade more or less into the matrix. Its maximum diameter is a little less than 60 mm. The maximum width of the whorls appears to be attained a little dorsad of their mid-height, and it is estimated that they are about half as wide as high (see text-fig. 5C).

The umbilicus is moderately small, and its diameter is equal to about one-sixth that of the conch. Its maximum diameter in the holotype is approximately 10 mm. The umbilical shoulders are subangular, and the umbilical walls are moderately steep. No trace of any surface markings can be seen.

As shown by text-figure 5D, each external suture consists of a long, slender, pointed, spatulate ventral lobe and on either side of it a narrowly rounded, asymmetrical, more or less U-shaped but laterally constricted first lateral saddle, a fairly short, broad, pointed, spatulate first lateral lobe, and a very wide, shallow, broadly rounded second lateral saddle which extends across the umbilical shoulder to a small pointed lobe on the umbilical wall.

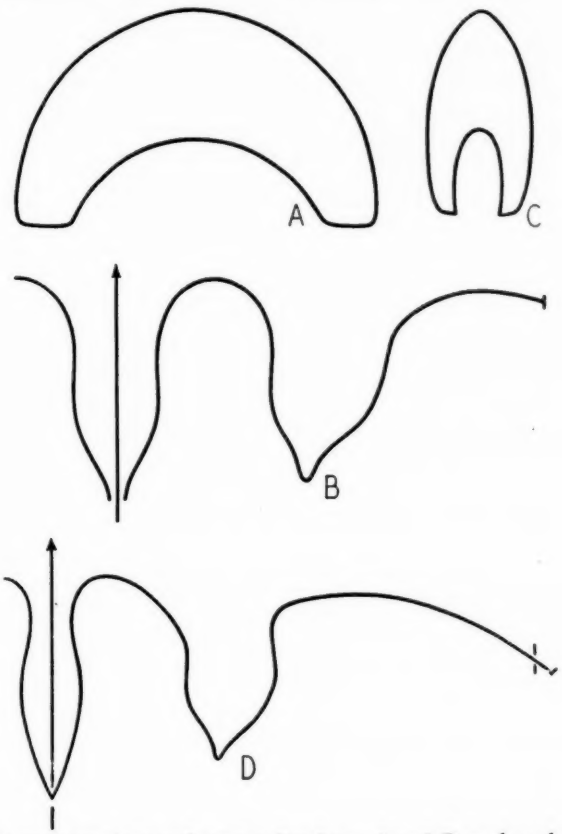


FIG. 5—Diagrammatic cross-sections and suture drawings. *A* and *B* are based on the adapical third of the outer volution of the specimen of *Gattendorfia* aff. *bransoni* represented by figures *1* and *2* on our plate 69, ×5 and ×10, respectively; *C* and *D* on the mid-portion of the adoral half volution of the holotype of *G. mehli*, X1 and ×2½, respectively.

Remarks.—This species does not seem to

be very close to the genotype, *Gattendorfia subinvoluta* (Münster) of the basal Lower Carboniferous of Germany (see pl. 69, fig. 18), but it is almost certainly congeneric with it. The German form seems to have a broader conch and a wider umbilicus, and its sutures, although consisting of the same number of elements, are considerably different in detail. In 1940 Librovitch described several species from the Lower Carboniferous of Kazakhstan that are somewhat closer to our form. Like the genotype, however, they appear to have relatively broad conchs, slightly wider umbilici, and sutures in which the first lateral lobes round much more gradually into the second lateral saddles. So far as we know, *G. mehli* does not closely resemble any previously described congeneric species, nor is it similar to any other form that occurs in association with it. The specific name is given in honor of Professor M. G. Mehl of the University of Missouri, who collected the holotype and many other specimens which we are studying.

Occurrence.—Lower portion of the Chouteau limestone, near Browns Station, about 8 miles northeast of Columbia, Boone County, Missouri.

Holotype.—University of Missouri, 3901.

GATTENDORFIA MINUSCULUM Miller & Collinson, n. sp.

Plate 68, figure 14; plate 69, figures 5, 6

The King Butte locality has yielded four small limonitic internal molds that clearly are referable to *Gattendorfia* but do not belong in any described species. Only one is not considerably crushed, and it (pl. 69, figs. 5, 6) is designated the holotype. This specimen is about 7 mm. in diameter. It is septate throughout and represents only phragmacone. It is thickly subdiscoidal or almost subglobular, and the whorls are broadly rounded ventrally and laterally and impressed dorsally. Near the adoral end the conch is about 5 mm. wide and 3 mm. high.

The umbilicus is moderately large, with a diameter about one-third that of the specimen. Its maximum diameter in the holotype is a little more than 2 mm. The umbilical shoulders are abruptly rounded and the umbilical walls are steep.

The internal mold bears about three rather large, rounded, transverse constrictions to the volution. Each forms a broad rounded sinus as it crosses the ventral zone of the conch. Between these constrictions faint traces of growth lines can be seen.

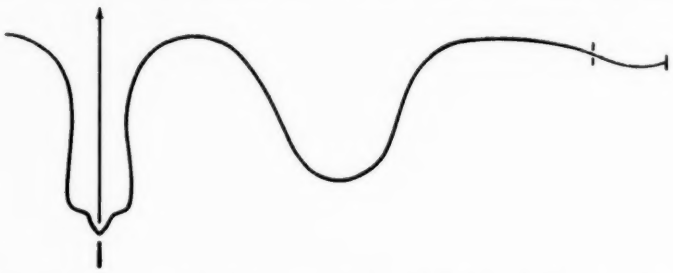


FIG. 6—Diagrammatic representation of an external suture of *Gattendorfia minusculum*, based on the mid-portion of the outer volution of the holotype, where the conch is about 2½ mm. high and 4 mm. wide; ×20.

Each external suture consists of a narrow, pointed ventral lobe with almost parallel sides, on each side of it a U-shaped first lateral saddle, a similar but more narrowly rounded first lateral lobe, and a shallower and more broadly rounded second lateral saddle which extends across the umbilical shoulder to a small lobe on the umbilical wall (text-fig. 6).

Remarks.—These specimens may be immature, but all are similar in size and all appear to be septate throughout. The rounded lateral lobes of the sutures differentiate this species from the other congeneric forms known, at least from America, but their shape may be merely a result of immaturity. Insofar as we have been able to ascertain, no specimens have been illustrated or described that are similar to these; thus

detailed comparisons seem unnecessary.

Occurrence.—Northview shale at King Butte (NE ¼ NE ¼ sec. 27, T. 31 N., R 22 W.), about 15 miles north of Springfield, Greene County, Missouri.

Types.—University of Missouri, 3962 (holotype and figured paratype), 4486 (crushed unfigured paratypes).

Genus MUNSTEROCERAS Hyatt, 1884
Genotype: GONIATITES OWENI PARALLELA Hall

The type species of this genus came from the Rockford limestone of Indiana, and it is well known, especially through the work of James Hall and J. P. Smith. It has a thickly subdiscoidal conch, small open umbilicus, constrictions on the internal mold which are essentially straight and directly transverse on the lateral zones but form a shallow rounded ventral sinus, and sutures that consist of eight lobes separated by rounded saddles. The ventral lobe of the sutures is deep, has almost parallel sides, and is divided medianly, whereas all of the other lobes are pointed (text-fig. 7).

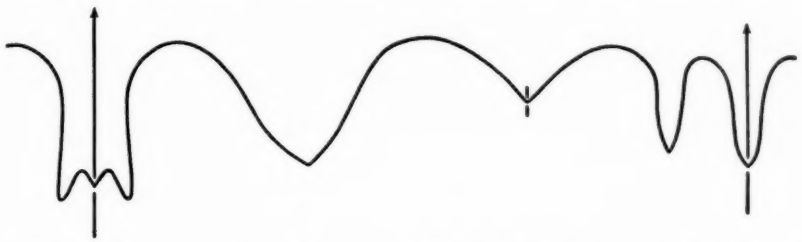


FIG. 7—Diagrammatic representation of a suture of the genotype *Munsteroceras parallelum*, from the Rockford limestone of Indiana, based on a small specimen, ×3¾; redrawn from J. P. Smith.

Strata of about the same general age as the Rockford, or a little younger, have yielded many forms that are similar enough to the genotype to be regarded as congeneric. They vary considerably in shape, as some are discoidal and others are subglobular. In all, the umbilicus is open, but its size varies within rather broad limits. Although the sutures differ in certain respects, they invariably possess a deep, narrow, divided ventral lobe in which the flanks are almost straight and more or less parallel, and the median secondary saddles are shallow. The shape of the ventral lobe seems to be the most diagnostic characteristic and differentiates representatives of this genus from such similar Carboniferous genera as *Beyrichoceras*, *Eoasianites*, etc., which do not occur in Kinderhook or Tournaisian faunas. Also, *Munsteroceras* and *Gattendorfia*, which are found in close association, can be readily distinguished only because the ventral lobe is divided in the former and pointed in the latter.

This genus, as now understood, is limited stratigraphically to the early Lower Carboniferous (Kinderhook and early Osage in North America). Geographically, however, it is widespread, being known also from Europe, Asia, Africa and Australia.

MUNSTEROCERAS? HOLMESII (Swallow)

Goniatites? Holmesii SWALLOW, 1860, St. Louis Acad. Sci. Trans., vol. 1, p. 659.

Muensteroceras? holmesi SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 13, 118, 145; MOORE, 1928, Missouri Bur. Geology and Mines, 2d ser., vol. 21, p. 100.

This species was based on a few internal molds that were lost in the fire at the University of Missouri in 1892. One of them was 25 or 26 mm. in diameter and none revealed the shape of the sutures. The original description is so brief and generalized that it is unsatisfactory for modern paleontological work, and it is not accompanied by an illustration.

Swallow seems to have been uncertain that this form was a goniatite. Smith, however, referred it doubtfully to *Munsterocercas* presumably because it is stated to have a conch that is "flattened, discoid, sharply rounded on the dorsal margin; umbilicus rather small infundibuliform; . . . [and] no constrictions" on the internal mold. It seems to us that the affinities of this species are so obscure that no specimens ever can be

referred to it with reasonable certainty.

Occurrence.—According to Swallow, this species is "rare in the Chemung [that is, Kinderhook] rocks of Cooper" County, Missouri, no more nearly precise locality being given. Smith (1903, p. 13) inadvertently listed this form from the "Marshall group of Michigan," but in his discussion of the species he does not state that it occurs there.

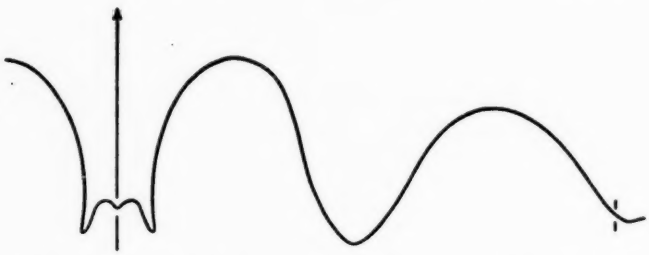


FIG. 8—Diagrammatic representation of a suture of *Munsteroceras medium*, based on the mid-portion of the outer volution of the holotype, where the conch is about 6 mm. high and 7½ mm. wide; ×7½.

MUNSTEROCERAS MEDIUM Miller & Collinson, n. sp.
Plate 69, figures 9, 10

The single specimen of this species is a limonitic internal mold, about 17 mm. in diameter, which is septate throughout. The conch is thickly subdiscoidal and the whorls are helmet-shaped in cross-section, as they are rather broadly rounded ventrally and laterally and are impressed dorsally. Near the adoral end the conch is about 8 mm. high and its corresponding width is estimated at about 10 mm. The side that is not figured is crushed and incomplete.

The umbilicus is moderately small, the umbilical shoulders are abrupt, and the umbilical walls are very steep. The maximum diameter of the umbilicus is about 3 mm.

The internal mold bears about five fairly distinct, but not especially prominent, rounded transverse constrictions to the volution. Each forms a shallow, rounded, ventral sinus. Faint traces of the growth lines can also be discerned, which appear to be parallel to the constrictions.

As shown by text-figure 8, each external suture forms a deep bifid ventral lobe and on either side of it a U-shaped first lateral saddle, a V-shaped first lateral lobe, and a moderately high rounded second lateral saddle. The internal sutures are not known.

Remarks.—This species seems to be a typical representative of *Munsteroceras*. It resembles the genotype in most respects, but its conch is relatively wide, and most of the numerous associated specimens are narrower. The transverse constrictions are much less prominent on the only figured specimen that has been referred to *M. osagense*.

Occurrence.—King Butte (NE ¼ NE ¼ sec. 27, T. 31 N., R. 22 W.), about 15 miles north of Springfield, Greene County, Missouri.

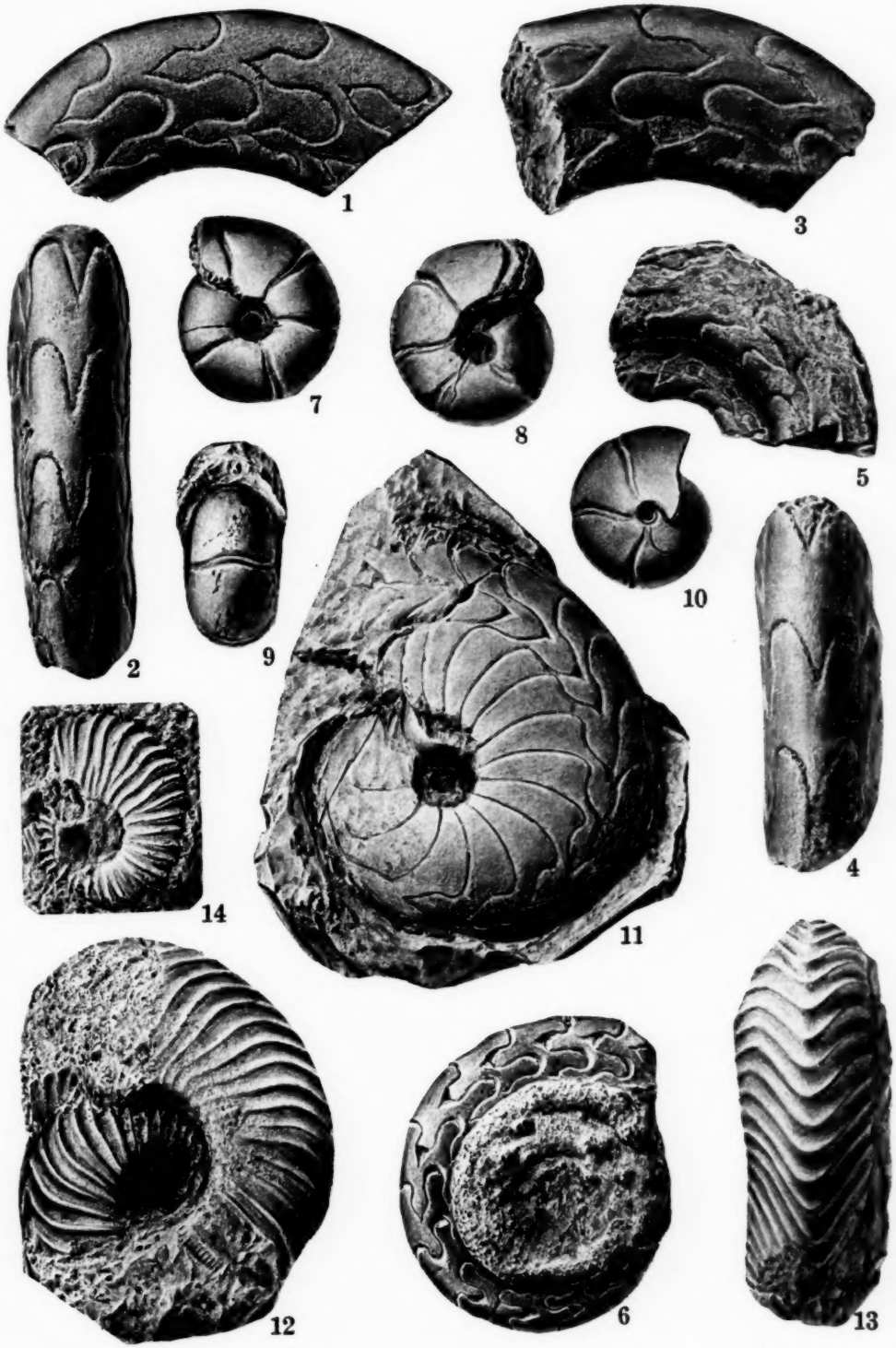
EXPLANATION OF PLATE 70

FIGS. *1–6*—*Protocanites lyoni* (Meek & Worthen). *1, 2*, A topotype from the Rockford limestone at Rockford, Indiana; ×1½. *3–5*, Two fragments, probably of the same individual, from the Chouteau limestone at Danville, Missouri; ×1½. *6*, A specimen from the Northview shale at King Butte, 15 miles north of Springfield, Missouri; ×1. (p. 479)

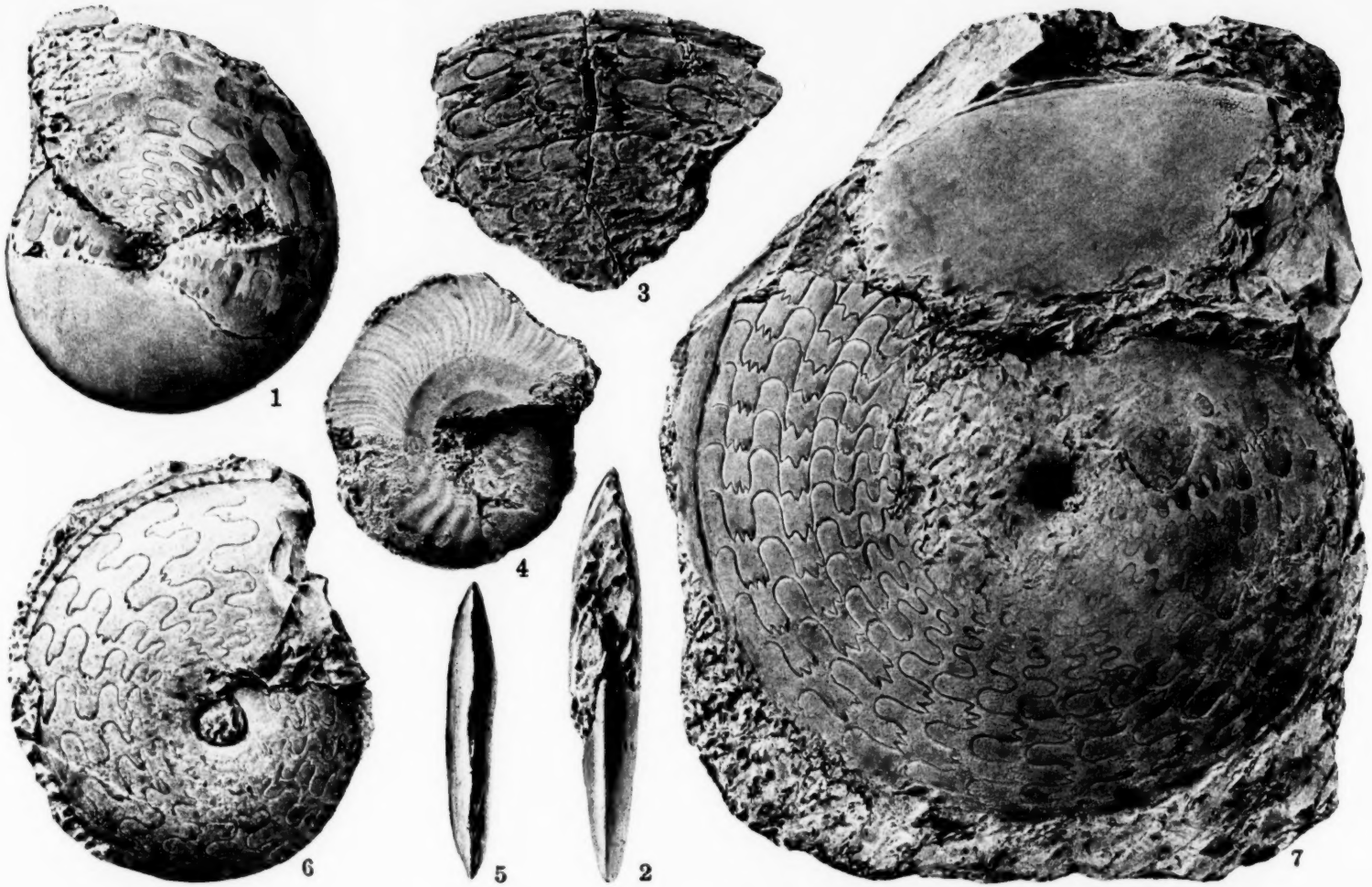
7–10—*Munsteroceras osagense* (Swallow)?. Three views of one specimen and a lateral view of all but the adoral portion of the same individual (showing a suture), from the Chouteau limestone of Pettis County, Missouri; ×2. *10* is adapted from Smith. (p. 473)

11—*Gattendorfia mehli* M. & C., n. sp. The holotype, from the lower portion of the Chouteau limestone near Browns Station, Missouri; ×1. (p. 469)

12–14—*Pericyclus blairi* (Miller & Gurley). *12, 13*, the holotype, from the Chouteau limestone 6 miles from Sedalia, Missouri; *14*, an artificial cast of a small specimen of uncertain affinities, from the same formation near Browns Station, Missouri; all ×2. (p. 475)



Miller and Collinson, Lower Mississippian ammonoids



Miller and Collinson, Lower Mississippian ammonoids

Holotype.—John Britts Owen Collection at State University of Iowa, 6798.

MUNSTEROCERAS? MORGANENSE (Swallow)

Goniatites Morganensis SWALLOW, 1860, St. Louis Acad. Sci. Trans., vol. 1, pp. 659–660.
Muensteroceras? morganense SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 13, 119.

The syntypes of this species, which were lost in the fire at the University of Missouri in 1892, were small individuals with diameters of only about 10 mm. Unfortunately, they did not reveal the shape of the sutures. The original description is brief and generalized and is not accompanied by an illustration. Presumably because the conch is said to be "gibbous, subdiscoidal, [and] broadly rounded on the dorsal margin" and to have a "small, deep, subinfundibuliform umbilicus" and slightly sinuous transverse constrictions, Smith referred this form doubtfully to *Munsteroceras*. Its affinities, however, are very questionable, and the species almost certainly can never be recognized.

Occurrence.—According to Swallow, this form is "very rare" in the Chouteau limestone of Missouri, no more precise locality being given.

MUNSTEROCERAS OSAGENSE (Swallow)
Plate 70, figures 7–10

Goniatites osagensis SWALLOW, 1860, St. Louis Acad. Sci. Trans. vol. 1, p. 659; [part ?] KEYES, 1894, Missouri Geol. Survey, vol. 5, p. 221; ? —— & ROWLEY, 1897, Iowa Acad. Sci. Proc., vol. 4, p. 36.
Muensteroceras osagense [part ?] SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 13, 14, 119, 145, pl. 24, figs. 8–12; [part ?] MOORE, 1928, Missouri Bur. Geology and Mines, 2d ser., vol. 21, pp. 68, 95, 100, 126, 187, 206; [part ?] MILLER, 1935, Am. Jour. Sci., 5th ser., vol. 30, pp. 432, 433, 434.

This species was based on several subdiscoidal specimens from the "Chemung" (that is, Kinderhook) strata of Cooper and Moniteau Counties in central Missouri that were lost in the fire at the University of Missouri in 1892. The diameter of one of them was stated to be about 22 mm. and the maximum width of conch was about 7 mm. The conch was flattened laterally and rounded ventrally, and bore sinuous transverse constrictions. The sutures were stated to form "a broad, shallow, forward curve on the sides, and a more abrupt backward sinus on the dorsal margin"; and they were said to differentiate this species readily from the otherwise similar *Beyrichoceras micronotum* (Phillips) of the Lower Carboniferous of England. Unfortunately, no figures or detailed descriptions were ever published.

Smith illustrated and described as a representative of this species a specimen (Walker Museum, Univ. Chicago, 8602) from the Chouteau limestone found at some unrecorded locality in Pettis County, Missouri, just west of the counties which yielded the types. In 1929 the senior author of the present report studied that individual and had it photographed, but it has since been misplaced. Smith's description is readily available, and there is accordingly no need to reproduce it, but we are including some new figures of the specimen. It seems to us that there is no good reason to believe that it is or is not conspecific with Swallow's syntypes. (See text-figure 9.)

Keyes, Keyes and Rowley, and Smith listed this species as occurring in the lower Burlington limestone at Louisiana in Pike County, Missouri; and Moore indicated that it is represented in the same general zone west of Osceola in St. Clair County of the same state. However, as stated by Miller,

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EXPLANATION OF PLATE 71

FIGS. *1–7*—*Prodromites gorbyi* (Miller). Five specimens representing various stages of ontogenetic development, from rather early (*6*, considerably enlarged) to late (*3*, *7*) maturity. *1*, *2*, The holotype of "*P. praematurus*" [=*P. gorbyi*], from the Rockford limestone at Rockford, Indiana; ×1; the portion of this specimen on which no sutures are shown is a restoration. *3*, Part of a phragmacone which retains the ventral keel, from the Chouteau limestone, 2 miles north of Browns Station, Missouri; ×1. *4*, *5*, The holotype of "*P. ornatus*" [=*P. gorbyi*], from the Chouteau in Pettis County, Missouri; ×1½. *6*, A small specimen from the Chouteau along Cedar Creek on the Hocker Farm, 3½ miles north of Sedalia, Missouri; ×3. *7*, The holotype of this species, from the Chouteau limestone at Pin Hook bridge in Pettis County, Missouri; ×1. All of these specimens retain portions of the ventral keel.

(p. 482)

none of the specimens on which these records are based has ever been illustrated or described, and since *Münsteroceras? osagense* was originally described from the Chouteau limestone (Lower Mississippian), it is rather doubtful if the specific identification of the Burlington form [or forms] is correct.

Occurrence.—According to Swallow, this species is abundant in the Kinderhook beds of Cooper and Moniteau counties, Missouri. Other possible occurrences of it are indicated above.

MUNSTEROCERAS? spp.
Plate 68, figures 12, 13; plate 69, figures 3, 4

The Chouteau limestone, especially the Northview phase or member of it, has yielded many rather poorly preserved, subdiscoidal to subglobular specimens with small open umbilici. Only a few of these retain their sutures and therefore can be identified generically with reasonable certainty. Their general form suggests that they belong in *Munsteroceras*, or possibly *Gattendorfia*. They range in diameter up to about 35 mm. The widths of their conchs are generally difficult to determine, as they are crushed, but most of them (see, for example, pl. 68, figs. 12, 13) are distinctly narrower than the other Chouteau species of Missouri, *M. medium* and *M. osagense*.

The specimen represented by figures 3 and 4 on plate 69 is from the Wassonville limestone of southeastern Iowa. It has a subglobular conch, open umbilici, and rather prominent sinuous transverse constrictions, but it does not reveal the nature of the sutures. Presumably it also is referable to *Munsteroceras* or *Gattendorfia*, but it does not seem to be very close to any of the other forms known from the Kinderhook strata of Iowa, Missouri or Illinois.

Occurrence.—Northview shale at King Butte (NE ¼ NE ¼ sec. 27, T. 31 N., R. 22 W.) about 15 miles north of Springfield, Greene County, Missouri (50 specimens); Chouteau limestone, Darnell farm, east bluff of Weaubleau Creek, near Weaubleau, Hickory County, Missouri (one specimen); Chouteau limestone on Shepard farm about ½ mile north of Georgetown, Pettis County, Missouri (one specimen); and Wassonville limestone at Kalona, Washington County, Iowa (two specimens).

Figured specimens.—John Britts Owen Collection at State University of Iowa, 6799 (pl. 69, figs. 3, 4), 13917 (pl. 68, figs. 12, 13).

Genus PERICYCLUS Mojsisovics, 1882
Genotype: GONIATITES PRINCEPS de Koninck

When this genus was established (Mojsisovics, 1882, p. 141), only two representatives of it were cited, and Hyatt (1884, p. 330) chose as the genotype the one listed first, *Goniatites princeps* de Koninck of the upper Tournaisian of Belgium. Delépine (1940, pp. 38–40, pl. 1, figs. 12–19) has restudied this species fairly recently, and we have drawn upon his work for illustrations of it. These are being included because no undoubted representatives of the genus are known from America, and our literature contains no figures of typical forms. Nevertheless, they are so widespread and abundant in Eurasia that at many localities the lower Viséan zone is known as the "*Pericyclus*-Stufe," although the genus also occurs in the underlying upper Tournaisian.

The type species and other very similar ones from Europe seem to indicate that the genus should consist of thickly subdiscoidal forms having moderately small open umbilici, prominent transverse ribs and constrictions, and sutures consisting of eight rounded saddles and a similar number of lobes, all pointed except the ventral one, which is deep and bifid with almost parallel flanks. As Schmidt (1929, p. 65) has pointed out, some of the species from Soviet Russia

FIG. 9—Diagrammatic representation of the external suture of *Munsteroceras osagense?* shown by figure *10* on plate 70, ×8; redrawn from J. P. Smith.

and America that have been referred to this genus are not typical. Some from central Asia have subglobular conchs and relatively large umbilici, and four American specimens have no constrictions and the transverse ribs form a deep ventral sinus, which was interpreted by Schmidt (1925, p. 511) as a primitive character. In some of the Eurasian species the ribs form a slight ventral sinus, and a deep one is characteristic of *P. trapezoidalis* Crick of the Lower Carboniferous of Ireland.

None of the American specimens is very complete, and the shape of their mature sutures is not revealed. Their affinities are very uncertain, and transverse ribs are not distinctive of *Pericyclus*, as they occur in several other genera of Carboniferous goniatites, for example, *Hunanites* Chao and *Pennoceras* Miller & Unklesbay. Nevertheless, in general form these American specimens seem to resemble the type species of *Pericyclus* closer than any other genotype with which we are familiar.

As now interpreted, *Pericyclus* is of widespread occurrence in the upper Tournaisian and especially the lower Viséan of Europe, and locally it seems to be abundant in beds of comparable age in the central Asiatic portion of Soviet Russia (Kirghiz Steppes and Tien Shan). The only specimens that have been found in America that may be referable to the genus came from the Chouteau limestone of Missouri and the Caballero formation of New Mexico.

PERICYCLUS? BLAIRI (Miller & Gurley)
Plate 70, figures 12–14

Goniatites blairi MILLER & GURLEY, 1896, Illinois

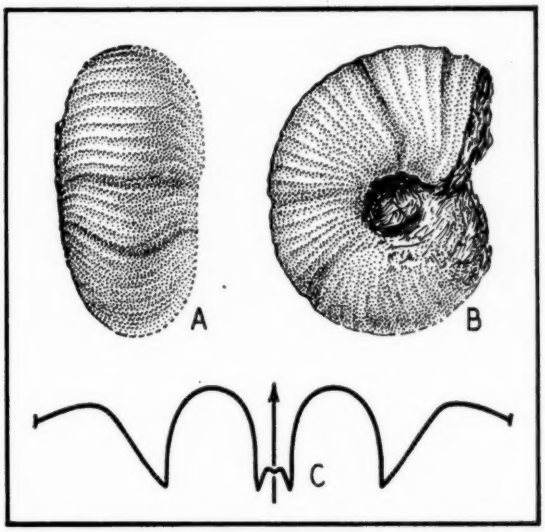

FIG. *10*—The holotype of the type species *Pericyclus princeps*, from the upper Tournaisian of Belgium. *A*, *B*, ×1; *C*, ×1¼. Adapted from Delépine.

State Mus. Nat. Hist. Bull. 11, pp. 35–36, pl. 4, figs. 4, 5.

Pericyclus blairi SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 13, 60–61, 144, pl. 16, figs. 4, 5; SCHMIDT, 1925, Preuss. geol. Landesanstalt Berlin, Jahrb. 1924, Bd. 45, pp. 511, 553; MOORE, 1928, Missouri Bur. Geology and Mines, 2d ser., vol. 21, p. 101; DELÉPINE, 1931, Cong. Soc. Savantes, 1928, C. R., p. 132; MILLER & YOUNGQUIST, 1947, Jour. Paleontology, vol. 21, p. 115, pl. 28, figs. 1, 2.

The only moderately well preserved holotype of the species is considerably distorted, and does not reveal the shape of its sutures or the nature of its inner volutions. It does, however, show that the conch is subdiscoidal, as the whorls are flattened laterally, rather narrowly rounded ventrally, and considerably impressed dorsally. The umbilicus is moderately large, and the umbilical shoulders abrupt. The specimen bears prominent subangular ribs which slope apicad from the umbilical shoulders on the

lateral zones of the conch, and on the ventrolateral zones curve more strongly in the same direction and then form a deep, almost subangular ventral sinus. The intermediate grooves are much wider than the ribs. This specimen is not complete adorally, but the preserved portion is about 28 mm. in diameter and attains a maximum height and width of conch of about 12 mm. and 10 mm., respectively. The maximum diameter of its umbilicus is about 11 mm.

From the same formation at a locality about 55 miles to the northeast we have two small fragmentary specimens that probably belong in this species. One of these is an external mold of part of a volution that does not seem to differ materially from the holotype, but is distinctly smaller. The other (pl. 70, fig. 14) also is much smaller and it represents only a single incomplete volution. The ribs of this individual seem to be increased in number by implantation, and also they branch in the region of the umbilical shoulder. No trace of sutures can be discerned on either, and their affinities are very uncertain.

Remarks.—Direct comparison of the holotype of this species with the specimen from the Caballero formation of south central New Mexico which Miller and Youngquist illustrated as *Pericyclus* cf. *blairi* has convinced us that they are probably conspecific. The difference in size of the umbilicus seems to result from crushing of the holotype in such a way that it seems relatively small, whereas the umbilicus of the Caballero specimen has been enlarged considerably by weathering. Unfortunately, the inner volutions of the latter specimen are not sufficiently well preserved to permit satisfactory comparison with the other. They do, however, retain traces of the septa which indicate that the camerae are moderate in length and that on both sides of the conch each suture forms a ventrolateral lobe and dorsad of it a broad, rounded lateral saddle and a small subangular lobe near the umbilical shoulder.

Although Eurasia has yielded many specimens that are now regarded as congeneric with *P. blairi*, most of them are not very similar. The deep ventral sinus formed by the ribs of the American species serves to distinguish it readily from almost all of these related forms. *P. trapezoidalis* Crick of the Lower Carboniferous of Ireland has similarly shaped ribs, conch and umbilicus, but it appears to be much larger and its surface bears fine longitudinal markings.

Occurrence.—Chouteau limestone, 6 miles from Sedalia in Pettis County (holotype) and near Browns Station in Boone County, Missouri, about 8 miles northeast of Columbia. The Caballero specimen was found in the Sacramento Mountains, sec. 14, T. 16 S., 10 E., Otero County, New Mexico.

Repositories.—University of Cincinnati, 3955 (holotype); and University of Missouri, 4499, 4500 (pl. 70, fig. 14). The Caballero specimen is also deposited at the latter institution.

Genus PROTOCANITES Schmidt, 1922
Genotype: GONIATITES LYONI Meek & Worthen

When Mojsisovics (1882, p. 199) established *Prolecanites*, he interpreted it rather broadly and cited as examples six species including "*Prolecanites mixolobus* (*Sandberger, non Phillips*); Sandberger, Nassau, Taf. III, Fig. 13 [excl. Taf. IX, Fig. 6[1]]" and *P. lyoni* (Meek & Worthen). The former was listed first, and it has come to be accepted as the genotype. Schmidt (1925, p. 541) stated that this form should be referred to *Goniatites serpentinus* Phillips; but in 1938 Miller expressed the opinion that it is specifically distinct from the figured type of that species, and he proposed the name *Prolecanites mojsisovicsi* for it. As shown by text-figure 11, the sutures of this species are not very close to those of *Goniatites lyoni* Meek & Worthen, for which Schmidt (1924, pp. 152–153) established the genus *Protocanites*. It now seems clear that *Prolecanites* and *Protocanites* are quite distinct from one another, and that the genotype of the former should probably be

[1] As Schindewolf (1926, pp. 74–75) has pointed out, *Goniatites mixolobus* Phillips is referable to *Pronorites*, as now interpreted. The specimen illustrated by figures 13 and 13a on plate 3 of the Sandberger brothers' report is the holotype of the genotype of *Prolecanites* s. s.; and the suture drawing numbered 6a on plate 9 of the same volume is probably composite, with its ventral lobe that of *Pronorites* and its lateral ones those of *Prolecanites*.

designated *Prolecanites mojsisovicsi*, whereas that of the latter is *Protocanites lyoni*.

The name *Protocanites* was used in print first by Paeckelmann (1922, p. 283), but in a footnote he stated that the genus is to be ascribed to Schmidt, who, in a manuscript then in press, was proposing it for "der Gruppe des '*Prolecanites*' *Lyoni* M. u. W."

It seems clear that this genus should include subdiscoidal goniatites with large open umbilici and whorls that are subrectangular in cross-section, as they are flattened laterally (with almost parallel lateral zones), broadly rounded ventrally and only slightly impressed dorsally. Each mature suture forms a more or less V-shaped ventral lobe, two pairs of undivided external lateral lobes, a pair of smaller umbilical lobes, and a deep spatulate dorsal lobe. Typically the saddles are rounded with the internal ones narrower than the external.

The type species of *Prolecanites* is known only from a fragment, and comparisons with it are not very satisfactory. Its sutures, however, are considerably different from those of typical *Protocanites* (cf. text-figs. 11A and 11B, C). In *Merocanites* Schindewolf the sutures resemble those of *Protocanites* but have one additional external lateral lobe on each side of the conch.

Typical representatives of *Protocanites* are of widespread occurrence in the United States, having been found in Virginia, Ohio, Indiana and Missouri, and at all of these localities their age is presumably Kinderhook. *Goniatites louisianensis* Rowley, which has been referred to this genus by several authors, is known only from very small specimens, all probably immature, and its

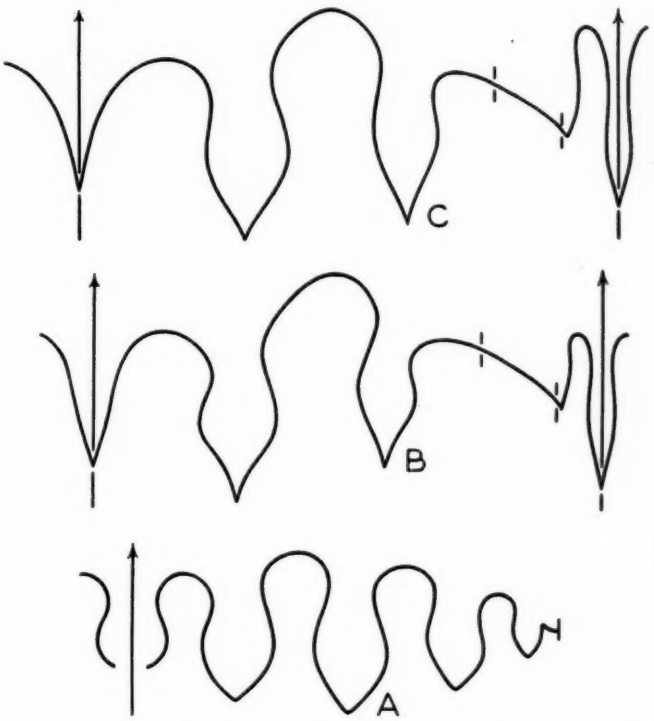

FIG. *11*—Diagrammatic representations of *A*, an external suture of the genotype *Prolecanites mojsisovicsi* from the Lower Carboniferous of Germany, and *B*, *C*, mature sutures of the type species *Protocanites lyoni*, from the early Mississippian of North America and probably equivalent beds in Europe, Asia and Australia. *A* is redrawn from G. and F. Sandberger, ×5; *B* is based on a topotype (State Univ. Iowa, 9545) from the Rockford limestone at Rockford, Indiana (pl. 70, *1*, *2*), ×3; and *C* is based on a specimen from the Chouteau limestone near Danville, Missouri (pl. 70, figs. *3*, *4*), ×3.

generic affinities are uncertain. Congeneric forms have long been known from northwestern Europe, and there has been difference of opinion as to the age of the beds there which contain them. Professor O. H. Schindewolf (personal communication dated January 5, 1950) has written recently that they are now all regarded as belonging in the early Lower Carboniferous (chiefly the lower and upper Tournaisian, but also the lower Viséan). Typical representatives of the genus have been found in north-central Asia and in southeastern Australia, and these likewise are believed to be early Lower Carboniferous in age.

PROTOCANITES GURLEYI (Smith)
Plate 69, figures 16, 17

Prolecanites gurleyi SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 13, 53, 144, pl. 24, figs. 1–4.

The holotype of this species is a moderately well preserved limonitic internal mold, discoidal in shape and about 16 mm. in diameter. It consists of approximately six volutions, all of which are completely septate. The conch is gradually expanded orad, almost as wide as high, and subcircular in cross-section, although slightly but distinctly impressed dorsally and very slightly flattened ventrally. Also in the adapical half of the outer volution there is a median rounded ventral groove. Near the adoral end the conch is about 5 mm. in diameter.

The umbilicus is open and wide, with a diameter of about 10 mm., but this is approximate because the umbilical shoulders are rounded and indefinite. No trace of any surface markings is discernible.

As indicated by text-figure 12, each external suture consists of five pointed spatulate lobes separated by similar but rounded saddles. The ventral lobe is slightly longer and more attenuated than the first lateral ones, which are considerably larger, longer, and more sharply pointed than the second lateral lobes. The third lateral saddles extend to the umbilical seams. They are asymmetrical and lower than the others. Smith stated that there is also "a short auxiliary lobe on the umbilical slope," and his diagrammatic representation of a suture shows such a lobe just outside one umbilical seam but not the other. We have examined the holotype closely for this lobe and are convinced that it does not exist, although there may be a lobe that centers on the umbilical seam.

The Greger Collection at Walker Museum of the University of Chicago contains a few very small goniatites from the same general zone and locality as the holotype just described. All of them seem to be quite immature, and, therefore, we are very uncertain as to their affinities. Their general form suggests that at least some may belong in this species.

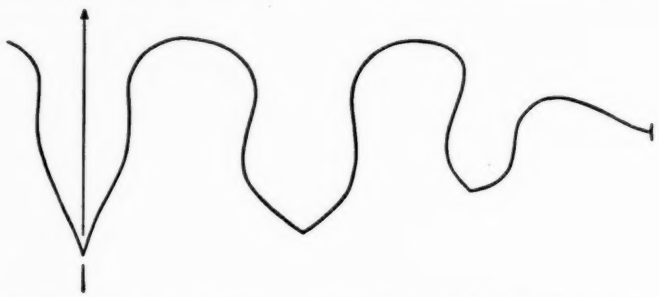

FIG. *12*—Diagrammatic representation of one of the adoral sutures of the holotype of *Protocanites gurleyi;* ×9.

Remarks.—Although this form is clearly congeneric with the genotype, *Protocanites lyoni*, they are so different that detailed specific comparisons are unnecessary. *P. gurleyi* seems to be closest to *P. greenii* (Miller) of the Kinderhook at New Albany, Indiana; the conch of the latter, however, is more rapidly expanded orad.

Occurrence.—Northview member of Chouteau formation, near Cedar Gap, Wright County, Missouri.

Holotype.—Walker Museum at University of Chicago, 8600.

PROTOCANITES? LOUISIANENSIS (Rowley)

Goniatites louisianensis ROWLEY, 1895, Am. Geologist, vol. 16, pp. 221–222, text-figs. 15–18; ——, 1908, Missouri Bur. Geology and Mines, 2d ser., vol. 8, pp. 30, 93, pl. 19, figs. 26, 27.

?Prolecanites? louisianensis SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 13, 54, pl. 6, figs. 6–8; MOORE, 1928, Missouri Bur. Geology and Mines, 2d ser., vol. 21, p. 47; LIBROVITCH, 1940, Paleont. U.S.S.R., vol. 4, pt. 9, fasc. 1, pp. 39, 207, 232, 318.

?Prolecanites? spp. MOORE, 1928, Missouri Bur. Geology and Mines, 2d ser., vol. 21, p. 47.

?Protocanites louisianensis SCHMIDT, 1925, Preuss. Geol. Landesanstalt Berlin, Jahrb. 1924, Bd. 45, pp. 511, 537; [part ?] WILLIAMS, 1943, U. S. Geol. Survey Prof. Paper 203, pp. 33, 108–109, pl. 9, figs. 33–40.

Rowley based this species on some small specimens from clay partings in the lower portion of the Louisiana limestone, and he supplemented his brief and generalized description with crude sketches of his largest individual, which apparently was about 6½ mm. in diameter. Later (1908) he republished the original description and accompanied it with two additional sketches of his "type specimen." Meanwhile, Smith (1903) had pointed out that it is "hardly possible" to determine the systematic position of the species from Rowley's original figures, and the same statement applies equally well to his later ones, which scarcely seem to represent the same individual. Smith illustrated another specimen from the type locality, and, presumably on the basis of it, he referred the species questionably to *Prolecanites*, which at that time was interpreted rather broadly. More recently, Williams (1943) has illustrated several more specimens and has discussed the species at some length.

We have not been able to locate the holotype or the material studied by Williams, but we have a small collection from the same source. These specimens are not very well preserved and the best of them has been crushed and distorted. Furthermore, because they are very small, we are inclined to believe that they are immature.

It seems very doubtful that the specimen figured by Smith is conspecific, or even congeneric with Rowley's holotype, and Williams appears to have had the same opinion. The specimens studied by us vary considerably and because we think that they are immature, we doubt that their affinities can be determined with reasonable certainty.

In our opinion this species, although valid, is unrecognizable. Little precise information is available regarding its holotype, which presumably has been lost and almost certainly represented only immature portions of the conch. Furthermore, collections from the same general zone and locality contain a variety of forms, but their affinities cannot be determined satisfactorily, for they too do not seem to be mature. No particular significance, therefore, should be attached to our tentatively associating this species with *Protocanites*, for some of the published drawings of the holotype seem to us to suggest a relationship to *Gattendorfia*.

Occurrence.—Clay partings of the Louisiana limestone at Louisiana and about 1 mile farther south, near the mouth of Buffalo Creek, Pike County, Missouri.

Repositories.—Gurley Collection in Walker Museum at University of Chicago (specimens studied by J. P. Smith); and John Britts Owen Collection at State University of Iowa, 13888.

PROTOCANITES LYONI (Meek & Worthen)
Plate 70, figures 1–6

Goniatites lyoni MEEK & WORTHEN, 1860, Acad. Nat. Sci. Philadelphia Proc. 1860, pp. 471–472; ——, 1866, Illinois Geol. Survey, vol. 2, pp. 165–166, pl. 14, figs. 11a–11c; HALL, 1879, Natural History of New York, pt. 6, Palaeontology, vol. 5, pt. 2, pp. 476–478, pl. 72, fig. 12; pl. 73, figs. 9–11, pl. 74, fig. 7; HERRICK, 1888, Denison Univ. Bull. Sci. Labs., vol. 4, p. 100, pl. 7, fig. 2; COOPER, 1888, idem., vol. 4, p. 127; HERRICK, 1895, Ohio Geol. Survey, vol. 7, p. 514, pl. 18, fig. 2.

Goniatites hyas HALL, 1860, New York State Cabinet, Ann. Rept. 13, p. 102, text-figs. 17, 18.

Prolecanites lyoni MOJSISOVICS, 1882, K.-K. geol. Reichanst., Abh., Bd. 10, p. 199; HAUG, 1898, Soc. géol. France Mém., Paléont., t. 7, no. 18, p. 62; FRECH, 1899, Die Steinkohlenformation, pl. 46a, fig. 11; ——, 1902, Beitr. Paläont. u. Geol. Österr.-Ungarns u. Orients, Bd. 14, pp. 62, 64, text-fig. 12c; SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 13, 37, 52, 53, 54–55, 56, 144, pl. 16, fig. 18, pl. 19, figs. 9–11; ? SPIEGELHALTER, 1910, Centralbl. f. Min., Geol. u. Paläont., Jahrg. 1910, pp. 506–510, text-figs. 1, 2; GRABAU & SHIMER, 1910, North American index fossils, Invertebrates, vol. 2, pp. 148–149, text-figs. 1398h–1398j; SCHINDEWOLF, 1922, Senckenbergiana, Bd. 4, p. 15, text-fig. 2a.

Protocanites lyoni [part] SCHMIDT [in Paeckelmann], 1922, Preuss. geol. Landesanstalt Berlin, Jahrb. 1921, Bd. 42, p. 283; [part] ——,

1924, idem, Jahrb. 1923, Bd. 44, pp. 152, 153, 163, pl. 8, figs. 14–18; [part] ——, 1925, idem, Jahrb. 1924, Bd. 45, pp. 492, 510, 522, 527, 536, 537, 538; ? SCHINDEWOLF, 1926, Deutsche geol. Gesell. Zeitschr., Bd. 78, Monatsber., p. 104; [part] SCHMIDT, 1929, Gürich's Leitfossilien, Lief. 6, p. 62, pl. 16, fig. 1 [not 2]; MILLER 1936, Jour. Paleontology, vol. 10, pp. 69–72, text-figs. 1–3; [part] DELÉPINE, 1931, British Assoc. Adv. Sci., Rep. 1930, p. 326; ——, 1931, Cong. Soc. Savantes, 1928, Lille, C. R., p. 132; [part] CAREY, 1937, Linnean Soc. New South Wales Proc. vol. 62, p. 350; [part] BROWN, 1937, idem, Proc., vol. 62, p. 353; LIBROVITCH, 1940, Paleontology U.S.S.R., vol. 4, pt. 9, fasc. 1, pp. 75, 78–84, 191, 193, 196, 197, 198, 199, 202, 203, 204, 206, 207, 249, 250, 313, 314, 315, 317, 318; DELÉPINE, 1940, Soc. Géol. France Comptes rendu, no. 7, p. 70; ——, 1940, Mus. royale histoire nat. Belgique Mém. 91, pp. 8, 19, 21, 27, 28, 32–34, pl. 1, figs. 1–3, 8, 9; ——, 1941, Annals and Mag. Nat. History, ser. 11, vol. 7, pp. 387–389, 390, 393, 394; MILLER & UNKLESBAY, 1943, Jour. Paleontology, vol. 17, p. 11, text-fig. 4F; SHIMER & SHROCK, 1944, Index fossils of North America, p. 567, pl. 231, figs. 21–23; MILLER, Jour. Paleontology, vol. 21, p. 19.

Goniatites clymeniaeformis DE KONINCK, 1880, Mus. royale histoire nat. Belgique Ann. sér. paléont., t. 5, pp. 93, 95–96, pl. 49, figs. 12–13a; FOORD & CRICK, 1897, Catalog. foss. Ceph. British Mus. (Nat. Hist.), Pt. III . . ., p. 257.

Prolecanites clymeniaeformis DELÉPINE, 1931, Cong. Soc. Savantes, 1928, Lille, p. 132.

Protocanites clymeniaeformis SCHMIDT, 1925, Preuss. geol. Landesanstalt Berlin, Jahrb. 1924, Bd. 45, p. 537; SCHINDEWOLF, 1926, Senckenbergiana, Bd. 8, p. 77; DELÉPINE, 1931, British Assoc. Adv. Sci. Rept., 1930, p. 327; LIBROVITCH, 1940, Paleontology U.S.S.R., vol. 4, pt. 9, fasc. 1, pp. 83, 202, 204, 315; DELÉPINE, 1940, Soc. géol. Nord. Annales, t. 64, pp. 137, 144.

Both the Chouteau limestone and the Northview shale of Missouri have yielded representatives of this species. These are incomplete but rather well preserved internal molds of phragmacones, and there seems to be no good reason to doubt that they are conspecific with topotypes, several of which are available to us for direct comparisons.

From the Chouteau we have two fragments, which apparently are parts of the same individual. Together they preserve portions of three volutions of the phragmacone. The lateral zones of the conch are flattened and almost parallel, the ventral zone is rounded, and the dorsal is slightly impressed. The shape of the cross-section does not appear to vary greatly in the three volutions represented. Near the adoral end of the larger fragment, the maximum height and width of conch are about 17 mm. and 12 mm., respectively, and the impressed zone is about 1 mm. deep. As shown by text-figure 11C, each suture forms a small V-shaped ventral lobe and on either side of it a rounded asymmetrically U-shaped first lateral saddle, a deep lanceolate first lateral lobe, a second lateral saddle that is higher than the first and more or less U-shaped but constricted laterally, a second lateral lobe that is similar to the first but smaller and shallower, an asymmetrical rather narrowly rounded saddle, a similar but subangular umbilical lobe which centers just inside the umbilical seam, and a moderately high, narrow, rounded internal first lateral saddle which extends to the deep, narrow, pointed, spatulate dorsal lobe. The shape of at least the lateral portions of the external sutures seems to be essentially the same in all three volutions represented. Furthermore, as shown by text-figure 11, the nature of the sutures is essentially the same as in equal-sized topotypes (cf. also pl. 70, figs. 1, 2).

The single conspecific individual known from the Northview is preserved in limonite and pyrite (see pl. 70, fig. 6). It is about 46 mm. in diameter, is crushed and considerably flattened laterally, and its inner volutions are not visible. Its general form, however, and particularly the shape of its sutures do not differ specifically from the Chouteau specimen just described.

Remarks.—The fact that the second lateral saddles of the external sutures are much higher than the first might be taken to suggest that the lobes which we have designated ventral and first lateral evolved from a ventral lobe which became trifid. Unfortunately, none of the material available enables us to ascertain the ontogenetic development of the sutures. If, however, this is comparable to that of a form which appears to be closely related, *P. supradevonicus* Schindewolf (1926, p. 105), the ventral and lateral lobes evolved quite independently.

Specimens which are identical or very closely similar to the species under consideration are also known from the Rockford limestone of south-central Indiana, the upper part of the Cuyahoga formation (the "Waverly freestone") of central Ohio, the

lower portion of the Price formation of western Virginia, the Calcaire de Vaulx (upper Tournaisian) of western Belgium, the "Sandsteine von Schönau" of southwestern Germany, the lower part of a "series of green marls" in northeastern Kazakhstan (central Asia), and the mid-portion of the Burindi series of northeastern New South Wales. There has been difference of opinion regarding the age of the beds at these widely separated localities, but if, as seems quite possible, they prove to be essentially contemporaneous, the "zone of *Protocanites lyoni*" will be of inestimable value for local and intercontinental correlations. None of the goniatites known to occur in association with *P. lyoni* at any of its widespread occurrences seem to be incompatible with this possibility.

Foord and Crick (1897, p. 257) stated that their species "*Prolecanites*" *discoides* "may possibly be de Koninck's *Gon. clymeniaeformis*," which Delépine (1940, pp. 32–34) has shown to belong in *Protocanites lyoni*. De Koninck's specific name was, as has long been known, preoccupied. The external sutures of his specimens form one less pair of lobes than do those of Foord's figured type, and therefore the two forms do not even belong in the same genus according to modern interpretations. "*P.*" *discoides* is probably referable to *Metacanites* Schindewolf.

Protocanites quadratus Schindewolf from the lower Viséan of Germany resembles *P. lyoni* but its volutions are distinctly lower and broader. Specimens from the *Gattendorfia*-Stufe ("Hangenberg-Kalk"), lower Tournaisian, of Germany, that were regarded by some authors as being very close to, if not identical with, *P. lyoni*, were shown by Schindewolf (1926, pp. 98–110) to represent a distinct species for which he proposed the name *P. supradevonicus*.

P. algarbiensis (Pruvost) of the early Lower Carboniferous of southern Portugal is also similar to *P. lyoni*. However, as noted by Delépine (1941, p. 389), the Portuguese species "has a larger number of whorls and a wider umbilicus; the section of the whorls does not become so high, as the shell increases in size; also, the ventral lobe is not V-shaped, but a little deeper and slightly wider about the middle."

Occurrence.—The labels which accompany the specimens we are describing indicate that one of them was secured by E. B. Branson from the Chouteau limestone at Danville, Montgomery County, Missouri; and that E. L. Clark procured the other from the Northview shale at King Butte (NE ¼ NE ¼ sec. 27, T. 31 N., R. 22 W.), about 15 miles north of Springfield, Greene County, Missouri. The species was originally described from the Rockford limestone at Rockford, Indiana. Its occurrence elsewhere in the United States and probably abroad is given in a preceding paragraph.

Figured specimens.—University of Missouri, 3977 (pl. 70, figs. 3–5); and State University of Iowa, 9544 (pl. 70, fig. 6) 9545 (pl. 70, figs. 1, 2)—the last is in the John Britts Owen Collection.

Genus PRODROMITES Smith & Weller, 1901

Genotype: GONIATITES GORBYI Miller

By far the most aberrant of all the Mississippian ammonoid genera is *Prodromites*. It is much more suggestive of the Triassic than the early Lower Carboniferous, and therefore its name was derived from "the Greek of scout or forerunner." All of the known representatives seem to have come from the Kinderhook strata of central United States, that is, the Chouteau limestone of Missouri, Iowa and Illinois, and the Rockford limestone of Indiana. Direct comparisons have convinced us that these probably represent only a single species. Altogether, we now have available for study more than thirty specimens, which is far more material than has ever been assembled by those who have previously published on the genus. Most of the specimens that have not been reported before were collected by John Britts Owen of Clinton, Missouri, and fortunately they illustrate various stages of ontogenetic development.

The conch, which is thinly lenticular in shape, attains a moderately large size (more than 150 mm.). On its narrow ventral zone it bears a small angular keel which during maturity is adventitious and is not an attenuate peripheral portion of the conch itself. The umbilicus is small and not at all prominent. The surface of the test bears inconspicuous sinuous transverse ribs, traces

of which are rarely preserved on internal molds. The sutures are ceratitic and consist of a small pointed lobe on the venter and on either side of it a series of rounded U-shaped saddles separated by intermediate lobes of which the ventral ones are finely digitate (text-fig. 14).

Smith (1903, p. 35) expressed the opinion that this form is related to *Beloceras* Hyatt of the Devonian and probably *Hedenstroemia* Waagen of the Triassic. He recognized that the resemblance to the former "is not close" and is merely a result of the fact that both genera have a compressed involute conch and septa that contain many elements, but he believed that the "agreement is fundamental," a conclusion which we can not accept. Although the sutures of *Hedenstroemia* are in general similar to those of *Prodromites*, as Smith noted, the Triassic forms have divided ventral lobes and first lateral saddles and they do not bear a ventral keel. Because of these facts and the great difference in their age, we are convinced that the resemblance is entirely superficial and that the two genera are not closely related and do not belong in the same family. Furthermore, unlike Delépine (1940, p. 30), we are inclined to believe that the similarity of the European Lower Carboniferous genus *Acrocanites* Schindewolf to *Prodromites* is more apparent than real. Representatives of that genus have a thinly lenticular conch and sutures which form a large number of lobes and saddles, but their umbilici are open, the lobes of their sutures are not digitate, and there is no ventral keel separate from the rest of the conch.

Schmidt (1929, p. 64) has expressed the opinion that *Prodromites* developed from the prolecanitids, presumably using that term in a rather broad sense. Although mature representatives do not resemble typical prolecanitids, the early ontogenetic stages of the sutures in this genus suggest that Schmidt was probably correct. Nevertheless, we would place *Prodromites* in a separate family, for which we here propose the name Prodromitidae, and we know of no forms that descended from it. Its ventral keel is unique among Paleozoic ammonoids but is quite similar to that of *Coilopoceras* Hyatt of the Cretaceous.

In 1931 Delépine (p. 132) stated that he had recognized a representative of this genus from the Tournaisian of Belgium, but he has recently written (personal communication dated May 5, 1950) that further study convinced him that the specimen belongs in *Acrocanites*. It is illustrated by figure 10 on plate 1 of his 1940 monograph on the Dinantian ammonoids of Belgium.

PRODROMITES GORBYI (Miller)
Plate 71, figures 1–7

Goniatites gorbyi MILLER, 1891, Indiana Dept. Geology and Nat. Res., Advance sheets of 17th An. Rep., p. 90, pl. 15, fig. 1; ——, 1892, idem, 17th An. Rep., p. 700, pl. 15, fig. 1; KEYES, 1894, Missouri Geol. Survey, vol. 5, p. 220.

Prodromites gorbyi SMITH & WELLER, 1901, Jour. Geology, vol. 9, pp. 257, 258, 259–261, pl. 6, fig. 1, pl. 7, fig. 1, pl. 8, figs. 1, 2; SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 13, 14, 34, 36, 37–39, 40, 41, 55, 121, 144, pl. 23, figs. 1, 2, pl. 25, figs. 1, 2; ——, 1913, Zittel-Eastman Textbook of palaeontology, 2d ed., vol. 1, p. 634, Text-fig. 1190; SCHMIDT, 1925, Preuss. Geol. Landesanstalt Berlin, Jahrb. 1924, Bd. 45, p. 510; ——, 1929, Gürich's Leitfossilien, Lief. 6, p. 64; DELÉPINE, 1940, Mus. royale histoire nat. Belgique Mém. 91, p. 28.

Prodromites praematurus SMITH & WELLER, 1901, Jour. Geology, vol. 9, p. 259, 261–262, pl. 8, figs. 3, 4; SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 13–36, 37, 40–41, 55, 121, 144, pl. 25, figs. 3, 4.

Prodromites ornatus SMITH, 1903, U. S. Geol. Survey Mon. 42, pp. 13, 39–40, 144, pl. 25, figs. 6–8.

The largest known representative of this species is almost 150 mm. in diameter, and only the adoral tenth-volution of it is nonseptate. We have not been able to estimate the length of the living chamber at maturity, but clearly it was more than a quarter of a volution. The mature cross-section is thinly lenticular as the whorls are strongly compressed and their lateral zones are flattened and converged ventrally (text-fig. 13). The ventral zone of the conch proper is narrowly rounded but bears a thin keel which is acutely angular ventrally and is triangular in cross-section, although its dorsal side is concave. Except during early ontogenetic stages this keel is separated from the rest of the shell by the ventral wall of the conch, and the sutures therefore do not cross it. It is, of course, present on the living chamber as well as the phragmacone. In large, fully mature individuals, the keel reaches a height of at least 4 mm.

The umbilicus is small and inconspicuous, and the umbilical shoulders are so indefinite that they may be considered nonexistent. Nevertheless, in at least the internal mold, the umbilicus is not entirely closed. The maximum width of conch is attained somewhat dorsad of the mid-height of the whorls.

On the surface of the test the growth lines form small, low sinuous transverse undulations. Each describes a ventral sinus and on either side of it a broad rounded ventrolateral salient, a similar but smaller lateral sinus centering somewhat dorsad of the mid-height of the conch and a slight dorsolateral salient (see pl. 71, fig. 4). Well preserved individuals also retain faint longitudinal markings, of which one, located near the maximum width of conch, is relatively prominent. For the most part, only faint traces of this ornamentation are retained on the internal mold. One fragment of a large specimen, comparable in size to the holotype, has rather prominent sinuous transverse ribs.

FIG. *13*—Schematic outline apertural view of the holotype of *Prodromites gorbyi;* ×1.

The diameter of our smallest specimen is almost 7 mm. and that of its umbilicus about 1½ mm. Near the adapical end of the outer volution the conch is only about 1½ mm. high, and it is rather narrowly rounded ventrally and somewhat flattened laterally —we estimate that it is about as wide as high. Within this volution the ventral zone of the conch becomes attenuate, but the keel thus formed does not appear to be separated from the rest of the shell. The adoral three-fifths of the volution are non-septate, and the maximum height attained by the conch is a little less than 4 mm. Slightly larger specimens from the same locality, and presumably from the same general zone, show that when the conch attained a height of about 5 mm. a row of small rounded depressions appeared on both sides of the internal mold near the base of the keel, and about 12 occur in the next quarter-volution. Apparently, at about this same stage the keel became separated from the rest of the conch by a distinct wall which the septa do not cross, as shown in the adapical portion of the outer volution of the specimen represented by figure 6 on plate 71, whose height of conch is only about 5½ mm. The small depressions or pits along the junction of the keel with the rest of the conch became more numerous in the adoral portion of this specimen, which also came from the locality that yielded the others just discussed. These pit-like depressions seem to become obsolete as maturity is approached, but they can be discerned clearly in all but the extreme adoral portion of the specimen illustrated by figures 4 and 5 on the same plate.

The ontogenetic development of the external sutures is illustrated by text-figure 14. The earliest stage we have observed is at a height of conch of about 1½ mm. Here the ventral lobe appears to be undivided, and on either side of it there are two rounded lobes and three rounded saddles, all of which decrease markedly in amplitude toward the

umbilicus. Where the conch is about 3 mm. high, the ventral lobe is trifid and some auxiliary lobes and saddles have been added. The secondary saddles in the ventral lobe prominent that it can be considered to evolve into three lobes (two of which are, of course, adventitious), the first lateral lobes become digitate, and more auxiliary

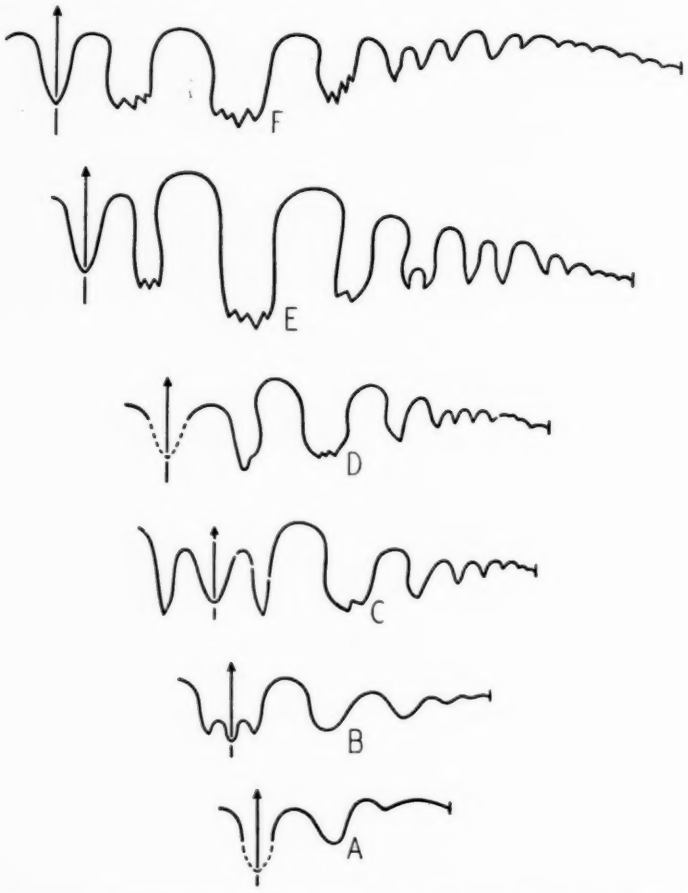

FIG. *14*—Diagrammatic representation of the sutures of *Prodromites gorbyi* during ontogenetic development. *A* and *B* portray rather early adolescent stages where the conch is about 1½ mm. and 3 mm. high, ×9 and ×10, respectively; *C* illustrates late adolescence where the height of conch (exclusive of the keel) is about 6 mm., ×6; *D*, *E* and *F* show three stages of maturity where the conch is about 7 mm., 28 mm., and 50 mm. high, ×6, ×2½ and ×1½, respectively. *D* is based on the midportion of the adapical half of the outer volution of the specimen represented by figure *6* on plate 71; *E* on the midportion of the adoral half of the outer volution of the specimen shown by figure *1* on the same plate.

then deepen and widen, all of the lobes tend to become pointed although the saddles remain rounded, and more auxiliary lobes develop on the umbilical portions. At a height of conch of about 6 mm. the first lateral lobes become slightly but distinctly bifid. As full maturity is approached the subdivisions of the ventral lobe become so lobes are added. Eventually, the adventitious lobes, the first and second lateral lobes, and even the largest of the auxiliary lobes become digitate, and the number of auxiliary lobes is increased to 12 or more. Some of the larger of the auxiliary lobes can be seen to become bifid and divide into two lobes. As might be expected, the details

of the digitation and the small auxiliary lobes appear to vary slightly in different specimens and even in the same individual. Such minor variations are affected greatly by preservation and interpretation.

Remarks.—As indicated in our generic discussion, direct comparison of a relatively large number of specimens has convinced us that the holotypes of *P. ornatus* Smith and *P. praematurus* Smith & Weller are conspecific with that of *P. gorbyi* (Miller), and all three are illustrated on our plate 71. Although the only specimen that has ever been referred to *P. ornatus* bears prominent surface markings which are not present on Miller's original type, we believe that this difference is largely a matter of preservation and, to a certain extent, ontogenetic development, for we have intermediate forms. Smith stated, "in *P. Praematurus* the abdomen is slightly broader, the shell rather thicker, the septa rather more complex, and the umbilicus slightly wider than on *P. gorbyi* at the same diameter." Our observations indicate that such differences, if they exist, are completely gradational. It seems to us that this species is so distinct from all other known forms that detailed comparisons are superfluous.

Occurrence.—All of the known representatives of this species came from the Chouteau limestone of Missouri, Iowa and Illinois, and the Rockford limestone of Indiana. The Missouri individuals are from the following localities: (1) Pin Hook bridge in Pettis County (holotype); (2) Hocker farm along Cedar Creek about 3½ miles north of Sedalia, also in Pettis County (eight specimens); (3) County Farm about 1½ miles north of Sedalia (four specimens); (4) roadside at Georgetown quarry near Sedalia (one specimen); (5) Shepard farm about ½ mile north of Georgetown (three specimens); unrecorded localities in Pettis County (holotype of "*P. ornatus*" and paratype figured by Smith and Weller and by Smith); (7) along Creagan Creek near Clifton City in Cooper County (four specimens); (8) near Easley and near Providence, in Boone County (two specimens); and (9) 2, 3½ and 4 miles, respectively, north of Browns Station, also in Boone County (five specimens). Iowa has yielded a single specimen; it is a well preserved completely septate internal mold about 75 mm. in diameter that does not retain the ventral keel and is entirely free of matrix. Smith, who illustrated it, stated that it came from Burlington "between the oolitic limestone and the buff magnesian bed that lies immediately below the Burlington" limestone, so presumably it is from the Chouteau as that formation is now interpreted. The only specimen known from Illinois was found at some unrecorded locality in Jersey County. This individual, a well preserved internal mold and the largest known representative of the species, is imbedded in matrix much like the Chouteau limestone of Missouri. Only two specimens seem to be known from the Rockford limestone, both from Rockford, Jackson County, Indiana. One of these is the holotype of "*P. praematurus.*" (See Addendum.)

Repositories.—Walker Museum at University of Chicago, 6208 (holotype), 6222 (Iowa specimen), 6223 (holotype of "*P. praematurus*"), 6474 (specimen from Pettis Co., Missouri, figured by Smith and Weller and by Smith), 7682 (holotype of "*P. ornatus*"); U. S. National Museum, 634 (Illinois specimen); University of Missouri, 3961, 3966, 3973, 3976 (pl. 4, fig. 3), 4683, 7219; and John Britts Owen Collection at State University of Iowa, 13921–13934. Text-figures 14A–D are based on three specimens numbered 14929, and 14F on one numbered 13924. Smith (1903, p. 39) stated that Fred. Braun of Brooklyn New York, had a large specimen from Rockford, Indiana, but it is not in his collection, which was purchased by Charles Schuchert for the Yale Peabody Museum.

ADDENDUM

After this report was written and while it was awaiting publication, Dr. Thomas R. Beveridge sent us two additional goniatites that he had recently collected from the Kinderhook of Missouri. Both of these are entirely free of matrix.

One of the specimens (S.U.I., 9548) is somewhat worn and crushed but is clearly referable to our species *Imitoceras abundans.* This individual is about 34 mm. in diameter, and almost all of its outer volution is nonseptate and therefore represents body chamber. It came from the basal portion of the

Chouteau limestone in an abandoned quarry in the SW ¼ NE ¼ NE ¼ sec. 15, T. 51 N., R. 19 W., southeast of Gilliam, Saline County, Missouri.

The other specimen (S.U.I., 9549), which is well preserved in pyrite, is an immature representative of *Prodromites gorbyi* (Miller) that is about 17 mm. in diameter. It is similar to the individual portrayed by figure 6 on plate 71 but is a little smaller and has somewhat more primitive sutures, a slightly larger umbilicus, and distinct lateral ribs—it does not retain the ventral keel. This individual came from the lower shales of the Northview formation along U. S. Highway 66 a few yards northwest of the "spur" to the town of Northview (SW ¼ SW ¼ SW¼ sec. 23, T. 30 N., R. 19 W.), Webster County, Missouri. It is particularly significant for it is the first representative of *Prodromites* to be recorded from the Northview.

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JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 4, PP. 488–513, PLS. 72–75, 2 TEXT FIGURES, JULY 1951

UPPER CRETACEOUS FORAMINIFERA FROM THE CARLSBAD AREA, SAN DIEGO COUNTY, CALIFORNIA

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ABSTRACT—Fifty-six species and varieties of Foraminifera are described and figured from Upper Cretaceous strata of the Carlsbad area, San Diego County, California. Fourteen species and varieties are described as new. The fauna correlates with that of the Tracian stage of the Great Valley of California, with the uppermost Taylor beds of the Gulf Coastal area and with the Campanian of Europe.

INTRODUCTION

THIS study is concerned with Foraminifera occurring in shale strata of Upper Cretaceous (Campanian) age in the northwestern part of San Diego County, California (fig. 1). The exact section is located on the ranch of Irwin J. Kelley, about 5 miles southeast of Carlsbad.

The Cretaceous strata of this locality are nearly flat-lying, dipping only about 3° to the northwest. The areal extent of the beds appears to be limited, probably not exceeding 2 or 3 square miles. An excellent section of the strata is exposed in the roadcuts along the highway to San Marcos where it rises to the upland surface on the south side of the Agua Hedionda valley. A contact with the crystalline basement complex occurs a few hundred yards to the east of the roadcuts.

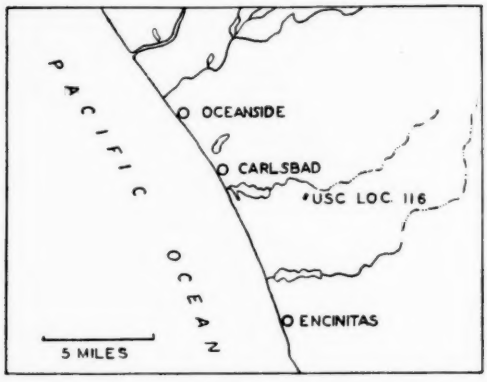


FIG. 1—Location of Kelley's Ranch Cretaceous area, USC Loc. 116.

Samples were collected throughout the exposed section in a dry ravine heading S. 35° W. from the head of Letterbox Canyon (see San Luis Rey quad., Calif., San Diego Co., 7.5 Min. Series, Topographic). The coordinates of the area are 117°17′ W. Long. and 33°08′10″ N. Lat. The samples were collected as follows:

L	105 feet	Top of shale, about 6 feet below upland.
K	90–102 feet	Composite of about 12 feet below L.
J	85–90 feet	Composite of 5 feet below K.
I	75–85 feet	Composite of 10 feet below J.
H	65–75 feet	Composite of 10 feet below I.
G	60 feet	5 feet below H.
F	55 feet	5 feet below G.
E	40–50 feet	Composite of 10 feet beginning about 5 feet below F, extending to fence line.
D	30–40 feet	Composite of 10 feet below the fence line.
C	20–30 feet	Composite of 10 feet below D.
B	10–20 feet	Composite of 10 feet below C.
A	0–10 feet	Composite of 10 feet below B, base of exposed section.

The total thickness of the shale is about 105 feet. It is overlain by a thin mantle of residual material. The shale is brownish and of nearly uniform character throughout the section. There are several thin beds of intercalated sandy limestone and associated with these are numerous megafossils. The unusual chamid, *Coralliochama orcutti* White, has a scattered occurrence in the upper part of the section.

FAUNAL CORRELATIONS

A comparison of this fauna with that from the Great Valley of California reveals many species common to both areas. Percentage-abundance counts (table 1) show that those forms occurring most abundantly

TABLE 1.—PERCENTAGE OCCURRENCES AND STRATIGRAPHIC RANGES OF THE UPPER CRETACEOUS FORAMINIFERA FROM KELLEY'S RANCH, SAN DIEGO COUNTY, CALIFORNIA

Species	(P) = 1 per cent or less (—) = Absent			Stratigraphic ranges in the Gulf Coastal Region as indicated by Cushman (1946)												
					TAYLOR						NAVARRO				
	Sample L	Sample E	Sample B	AUSTIN	Lower Taylor	Selma (middle)	Wolfe City	Pecan Gap	Annona Chalk	Upper Taylor	Neylandville	Upper Selma	Ripley	Nacatoch	Corsicana
Anomalina henbesti	30	6	P			×				×	×		×		
Apiopterina apiculata	P	—	—												
Bermudezina extans	—	—	P												
Bolivina incrassata	P	P	3		×	×	×	×	×	×	×	×	×		
Bulimina aspera	P	—	—		×	×	×	×	×	×	×				
Ceratobulimina cretacea	P	4	P									×	×	×	×
Cibicidina californica	—	P	2												
Colomia californica	—	5	—												
Colomia californica var. *mundula*	—	2	—												
Dentalina aculeata	P	—	—												
Dentalina angusticostata	2	—	—												×
Dentalina basiplanata	4	P	P		×	×	×	×	×	×	×	×	×	×	×
Dentalina marcki	P	P	2												
Dentalina megalopolitana	P	P	P			×		×	×	×	×				
Dentalina cf. *pseudofiliformis*	P	P	P												
Dentalina stephensoni	6	P	—		×	×		×	×	×	×				×
Dentalina wimani	4	2	P												
Dorothia bulletta	P	—	—	×	×	×				×		×	×	×	×
Frondicularia archiacina	P	P	—		×	×	×	×	×	×			×		×
Frondicularia goldfussi	P	P	P	×	×	×		×	×	×					
Gaudryina arguta	—	P	—												
Glandulina cf. *lagenoides*	—	—	P			×				×		×	×		×
Globigerinella aspera	P	P	3												
Globotruncana arca	9	10	P							×	×				
Globotruncana canaliculata	4	P	—	×	×		×	×	×	×	×				
Globotruncana rosetta	P	P	P												
Gümbelina striata	P	P	P	×	×	×		×		×					
Gyroidina globosa var. *orbicella*	3	22	19												
Höglundina supracretacea	2	2	25		×		×	×		×	×	×	×	×	×
Lagena acuticosta var. *brevipostica*	P	P	—												
Lagena acuticosta var. *proboscidialis*	P	P	P												
Lagena laevis var. *stavensis*	P	P	P												
Loxostomum plaitum	2	3	—		×	×				×	×	×	×	×	×
Marginulina bullata	P	2	P		×	×	×	×	×	×			×		
Marginulina directa	P	—	—	×	×		×								
Marginulina similis var. *obliquinodus*	P	P	—												
Marssonella oxycona	P	P	P	×	×			×	×	×				×	
Nodosaria amphioxys	P	—	—			×				×	×				
Nodosaria septemcostata	P	P	—												
Palmula primitiva	P	P	—					×		×					
Planularia multicostata	P	P	—		×	×		×	×	×	×	×	×		×
Planularia navarroana	P	P	—											×	×
Planulina mascula	5	24	P												
Planulina multipunctata	P	P	38												
Pseudouvigerina cretacea	—	P	P	×						×		×	×		
Quinqueloculina sp.	P	P	—												
Robulus modestus	3	P	—												
Robulus pseudocultratus	P	P	—												
Saracenaria navicula	—	P	—												
Saracenaria subglobosa	P	—	—												
Saracenaria triangularis	4	2	P	×	×		×	×	×	×			×		
Vaginulina plummerae	8	P	—												×
Valvulineria allomorphinoides	P	3	—	×	×						×		×		
Valvulineria nonionoides	P	—	—												
Valvulineria cretacea	7	P	—		×				×	×	×				×
Virgulina tegulata	P	P	—	×	×	×		×		×			×		
				10	19	16	9	16	13	24	14	9	15	7	13

are, in general, indices of the Tracian stage (fig. 2 of Goudkoff, 1945). Table 2 lists the most abundant forms (10 per cent or more) with their reported ranges in the Great Valley indicated on the right.

None of the abundant diagnostic forms occur characteristically outside of the D and E stages, and the primary diagnostic form, *Anomalina henbesti*, is limited to the E stage with only an occasional occurrence in the F-1 stage.

Comparisons with faunas of the Gulf

Coastal Cretaceous indicate correlation with the Taylor marl. An examination of the reported occurrences of the California species (table 1, column C) shows that this fauna has the most species in common with the upper Taylor. Goudkoff (1945, table 1) placed the Tracian stage (*Anomalina henbesti*, E zone) in the lowermost Navarro; from the preceding evidence (table 1) the *Anomalina henbesti* zone of California is perhaps more satisfactorily placed in the uppermost Taylor than in the lowermost Navarro.

TABLE 2

	A-2	B	C	D-1	D-2	E	F-1	F-2	G-1	G-2
Anomalina henbesti						O	×			
Höglundina supracretacea	×		×	×	×	O	×	×		
Globotruncana arca				×	O	O	×	×	×	
Glyroidina globosa var. *orbicella*	Previously unreported									
Planulina mascula	Previously unreported									
Planulina multipunctata	Previously unreported									

O = Characteristic occurrence.
× = Occasional occurrence.

For general correlation it is considered desirable to place emphasis upon the common (10 per cent) pelagic foraminifer, *Globotruncana arca* (Cushman). According to Glaessner (1945, p. 207) this pelagic form is characteristic of the boundary between the Santonian and Campanian and is replaced by a single-keeled form in the upper Campanian and Maestrichtian. In addition, the absence of typical Maestrichtian forms such as *Pseudotextularia*, *Globorotalia*, *Globigerina* and the conical species of *Globotruncana*, would tend to eliminate Maestrichtian age as a possibility. In view of the foregoing considerations and the fact that the Taylor beds are generally correlated with the Campanian (Schuchert, 1943, p. 960), the Kelley Ranch fauna is considered to be Campanian in age.

PALEOECOLOGY

It would be manifestly suspect to attempt precise ecologic interpretations from a fauna in which all of the species and even a few of the genera are extinct. There are possibly two criteria which might be indicative of the general conditions, however. These are predicated on the general faunal distribution of Recent Foraminifera in the Gulf of Mexico (Lowman, 1949, fig. 13).

The first criterion is based upon the preponderance of rotaloids in the fauna. Indicated on Lowman's figure 13 is a rather significant abundance of diverse genera, mostly rotaloids, in depths from about 100 feet to 350 feet. In the Kelley Ranch Cretaceous rotaloids make up approximately 50 per cent and nodosaroids from 6 per cent to 30 per cent of the fauna. The abundance of rotaloids may then indicate the middle neritic zone as being the site of deposition of the associated sediments.

The second criterion is based on the associated planktonic components. In Lowman's work the normal neritic fauna in depths of 100 feet to 300 feet bears an associated planktonic fauna amounting to about 3 per cent to 10 per cent of the total foraminiferal assemblage. In the Kelley Ranch material the planktonic element (*Globotruncana* and *Globigerinella*) makes up about 3 per cent of the fauna at the base of the section, about 10 per cent near the middle and about 13 per cent at the top of the section. From this information one might infer that the fauna represents a middle (?) neritic zone; however, this factor may also be governed by current activity and is therefore, perhaps, of little importance.

ACKNOWLEDGMENTS

Mr. R. E. Stevenson, Geology Department, University of Southern California, discovered the occurrence of foraminifers in the Cretaceous strata of the Carlsbad area and he made the first collections of

Group	European Stage		California Stages	California Foraminiferal Substages
Moreno	Maestrichtian		Garzas	A-1, A-2 Cheneyan
			Quinto	B, C′ Ciervian
			Moreno	D-1, D-2 Ingramian
Panoche	Senonian	Campanian	Los Gatos	E Tracian-Kelley Ranch Fauna
			Joaquin	F-1, F-2 Weldonian
		Santonian	Butte	G-1, G-2 Cachenian
		Coniacian	Yolo	
Pioneer		Turonian	Bellavista	H Delevanian
		Cenomanian	Gaines	

FIG. 2—Correlation table for the Upper Cretaceous of California. Adapted from Goudkoff (1945) and Anderson (1943).

them. Many thanks are due him for his kindness in turning his collections over to the writer for use in this study.

The writer is also greatly indebted to the following people for their kindness and cooperation in furnishing topotype material and for comparing specimens with types: Dr. Pedro J. Bermudez, Creole Petroleum Corporation, Caracas, Venezuela; Mrs. Helen Jeanne Plummer, Geologist, Bureau of Economic Geology, Austin, Texas; and Miss Ruth Todd, Research Associate, Cushman Laboratory for Foraminiferal Research. Dr. Brooks F. Ellis, Chairman, Department of Micropaleontology, The American Museum of Natural History, New York, has kindly furnished information from original sources on taxonomic phases of the study.

The types were drawn by the author and are deposited in the Paleontological Collection, University of Southern California, Los Angeles, California.

SYSTEMATICS

Order FORAMINIFERA d'Orbigny, 1826

Family MILIOLIDAE d'Orbigny, 1839

Genus QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA sp.

Plate 72, figures 1a–c

Two poorly preserved specimens of *Quinqueloculina* were found in sample E.

Plesiotype.—USC No. 603, sample E.

Family ATAXOPHRAGMIIDAE Schwager, 1877

Genus DOROTHIA Plummer, 1931

DOROTHIA BULLETTA (Carsey)

Plate 72, figures 4a, b

1926. *Gaudryina bulletta* CARSEY, Texas Univ. Bull. 2612, p. 28, pl. 4, fig. 4; Upper Cretaceous, Texas.

1931. *Dorothia bulletta*, PLUMMER, idem, Bull. 3101, p. 132, pl. 8, figs. 13–17; Upper Cretaceous, Texas.

1946. *Dorothia bulletta*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 46, pl. 12, figs. 21–26; Upper Cretaceous, southeastern U. S.

1949. *Dorothia bulletta*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 248, pl. 21, fig. 13; Upper Cretaceous, Maryland.

1949. *Dorothia bulletta*, CUSHMAN, U. S. Geol. Survey Prof. Paper 221–A, p. 3, pl. 1, fig. 20; Upper Cretaceous (Arkadelphia marl of Navarro age), Arkansas.

Test stout, early portion bluntly conical, later part subcylindrical; early chambers arranged in a trochoid spire, about five

chambers per whorl, then reducing rapidly to four, three and finally two chambers per whorl throughout the adult stage; early chambers uninflated, biserial chambers slightly inflated; sutures flush in the early part, becoming slightly depressed and nearly transverse to the axis of the test in the adult portion; wall finely arenaceous with much cement and smoothly finished; aperture a low arch at the base of the last septal face with a slight upper lip. Length of plesiotype, 0.70 mm.; diameter, 0.35 mm.

In the California specimens the final chamber is frequently distorted as indicated in the figure.

Plesiotype.—USC No. 574, sample L.

Genus GAUDRYINA d'Orbigny, 1839
GAUDRYINA ARGUTA Bandy, n. sp.
Plate 72, figures 3a, b

Test rather short, tapering to a blunt initial end, early portion rounded-trihedral, later portion ovate in cross-section; chambers rather indistinct in the early part, about three sets of triserially arranged chambers in the early part, about four to five sets of biserially arranged chambers in the adult portion; sutures nearly flush, nearly at right angles to the axis of the test; wall finely arenaceous, smoothly finished; aperture an elongate low arched opening at the base of the last septal face. Length, 0.50 mm.; breadth, 0.31 mm.; thickness, 0.21 mm.

The general shape of this form is similar to one reported by Cushman and others as *Dorothia conula* (Reuss) (Cushman, 1946); however, this species has a blunt and rather clearly defined triserial early part and is generally not as lobate. Reuss' type was not figured and the several subsequent plesiotypes differ considerably from one another.

Holotype.—USC No. 578, sample E.

Genus BERMUDEZINA Cushman, 1937
BERMUDEZINA EXTANS Bandy, n. sp.
Plate 72, figures 2a, b

Test roughly trihedral in the early part, flattened oblong in section in the later portion, greatest breadth near the apertural end; periphery lobate in the later part, early portion smooth to slightly lobate; chambers arranged three to the whorl in the early portion becoming quickly triserial and trihedral, then biserial for the last three-quarters of the test, chambers somewhat inflated in the later part, only slightly so in the early part; sutures very slightly depressed in the early part, considerably depressed in the biserial portion; wall arenaceous but rather smoothly finished for the most part, aperture in adult an elongate oblong vertical opening with a distinct lip located just above the base of the last septal face. Length of holotype, 0.71 mm.; breadth, 0.37 mm.; thickness, 0.32 mm.

This is apparently the first reported *Bermudezina* from strata as old as the Cretaceous.

Holotype.—USC No. 587, sample C.

Genus MARSSONELLA Cushman, 1933
MARSSONELLA OXYCONA (Reuss)
Plate 72, figures 8a, b

1860. *Gaudryina oxycona* REUSS, Akad. Wiss. Wien. Math.-naturwiss. Kl., Sitzungsber., vol. 40, p. 229, pl. 12, fig. 3.
1933. *Marssonella oxycona* CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 9, p. 36, pl. 4, figs. 13a, b.
1945. *Marsonella oxycona*, GOUDKOFF, Am. Assoc. Petroleum Geologists Bull., vol. 29, p. 968 (chart); most characteristic of the Tracian (lower Navarro equivalent), California.
1946. *Marssonella oxycona*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 43, pl. 12, figs. 3–5; Mal Paso shale, Peru; Navesink marl, Mt. Laurel sand, New Jersey; Prairie Bluff chalk (Navarro), Alabama; Saratoga chalk (Navarro), Arkansas; Taylor and Austin, Texas. (See this reference for complete synonymy to 1946.)
1946. *Marssonella* cf. *oxycona*, SCHIJFSMA, Meded. van de Geologische. Stichting, ser, c, v. 167, p. 38, pl. 1, figs. 12a, b; Campanian, Southern Limburg.
1949. *Marssonella oxycona*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 248, pl. 21, fig. 11; Upper Cretaceous, Maryland.
1949. *Marssonella oxycona*, HOFKER, Institut royal des Sciences nat. Belgique Mém. 112, pp. 12–13; fig. 6; upper Senonian, South Limburg.

Test conical, round in cross-section, tapering, apertural end flat; early portion with four to five chambers per whorl, later reduced to three and then two in the adult; chambers closely appressed, simple; sutures flush; wall arenaceous, smoothly finished

to slightly roughened; aperture a low slit-like opening at the inner margin of the last chamber with a broad valvular tooth. Length of plesiotype, 0.60 mm.; diameter, 0.44 mm.

Plesiotype.—USC No. 594, sample E.

Family NODOSARIIDAE Schultze, 1854
Genus ROBULUS Montfort, 1808
ROBULUS MODESTUS Bandy, n. sp.
Plate 72, figures 9a, b

Test lenticular, close-coiled, biumbonate, with distinct umbonal areas of clear shell material, flush with the surface; edge acute; periphery smooth; chambers about seven to nine in number, very gradually increasing in size as added, the last one or two tending to become evolute; sutures flush, tangential, slightly curved, narrowly limbate; wall calcareous, smooth, finely perforate; aperture at the outer edge of the last septal face, radiate with about eight teeth and a narrow apertural extension downward into the septal face. Diameter of plesiotype, 0.69 mm.; thickness, 0.24 mm.

This species is similar to *R. münsteri* (Roemer) (1839, Verstein. norddeutschen Oolithen begirges, Nachtrag., p. 48, pl. 22, fig. 29) differing mainly in having tangential rather than radial sutures. Specimens assigned to *R. münsteri* by Cushman (1946, p. 53, pl. 17, figs. 3–9) may include forms which belong in this species.

Holotype.—USC No. 604, sample E.

ROBULUS PSEUDOCULTRATUS Cole
Plate 72, figures 5a, b

1927. *Robulus pseudocultratus* COLE, Bull. Am. Paleontology, vol. 14, no. 51, p. 19, pl. 1, fig. 5; Eocene, Guayabal formation, Mexico.
1946. *Lenticulina rotulata*, CUSHMAN (not Lamarck), U. S. Geol. Survey Prof. Paper 206, p. 56, pl. 19, figs. 1–7; not pl. 18, fig. 19; Upper Cretaceous, lower Navarro, Taylor and Austin beds, Texas, Mississippi and Alabama.

Test biumbonate, close-coiled, with a fairly broad flat transparent keel; chambers eight to ten in the last whorl increasing very gradually in size as added; sutures distinct, curved and tangential, terminating at the center in the central clear umbonal areas; wall smooth, finely perforate; apertural face small, aperture at the outer edge of the septal face, radiate, with approximately ten teeth, and with an extension downward a short distance on the septal face. Diameter of plesiotype, 0.85 mm.; thickness, 0.45 mm.

Plesiotype.—USC No. 605, sample L.

Genus SARACENARIA Defrance, 1824
SARACENARIA NAVICULA (d'Orbigny)
Plate 72, figures 12a, b

1840. *Cristellaria navicula* D'ORBIGNY, Soc. géol. France Mém., 1st ser., vol. 4, p. 27, pl. 2, figs. 19, 20; Upper Cretaceous, Paris Basin.
1845. *Cristellaria navicula*, REUSS, Versteinerungen böhmischen Kreide-formation, pt. 1, p. 34, pl. 12, fig. 27.
1932. *Lenticulina navicula*, CUSHMAN & JARVIS, U. S. Nat. Mus. Proc., vol. 80, art. 14, p. 24, pl. 7, figs. 5a, b; Upper Cretaceous Trinidad.
1941. *Lenticulina navicula*, CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 17, p. 65, pl. 16, figs. 11a, b.
1946. *Lenticulina navicula*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 56, pl. 18, fig. 16; Upper Cretaceous, Trinidad, Mexico.

Test robust, planispiral tending to uncoil, triangular in cross-section; edge angled, periphery smooth; apertural face inflated somewhat; chambers variable, usually about seven visible, increasing in size gradually as added; sutures distinct, flush, evenly curved, surface smooth, finely perforate; aperture round, radiate. Length of plesiotype, 1.00 mm.; breadth, 0.72 mm.; thickness of last chamber, 0.44 mm.

This species is characterized by a triangular cross-section and it is therefore placed in the genus *Saracenaria* Defrance, 1824.

Plesiotype.—USC No. 606, sample E.

SARACENARIA SUBGLOBOSA Bandy, n. sp.
Plate 72, figures 10a, b

Test robust, triangular in transverse section, outer edge acute in the early portion becoming abruptly rounded in the adult portion; inner angles rounded; chambers varying from about six to nine or ten in the visible portion, closely appressed, early chambers in a nearly complete whorl, later chambers evolute, slanting down toward the coiled portion; sutures flush, curved, somewhat limbate toward the outer edge; surface smooth, finely perforate; apertural face elongate, fairly broad, convex; aperture terminal, radiate with about 12 teeth and a short narrow extension downward into

the septal face. Length of holotype, 0.54 mm.; breadth, 0.33 mm.; thickness, 0.25 mm.

The robust character together with the rounded apertural face and edges as seen in the apertural view are diagnostic.

Holotype.—USC No. 607, sample C.

SARACENARIA TRIANGULARIS (d'Orbigny)
Plate 72, figures 11a, b

1840. *Cristellaria triangularis* D'ORBIGNY, Soc. géol. France Mém., 1st. ser., vol. 4, p. 27, pl. 2, figs. 21, 22; Upper Cretaceous, France.
1936. *Astacolus jarvisi* BROTZEN, Sveriges geol. undersökning, ser. C, no. 396, p. 56, pl. 3, figs. 5a, b; text-fig. 17; lower Senonian, Sweden.
1946. *Saracenaria triangularis*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 58, pl. 28, figs. 1–3; Upper Cretaceous of the Gulf Coastal plain, U. S. (For a complete synonymy to 1946 see this last reference and also the Catalogue of Foraminifera, Special Pub. 1- , Amer. Mus. Nat. History, 1940– .)
1949. *Saracenaria triangularis*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 253, pl. 22, fig. 16; Upper Cretaceous, Maryland.

Test triangular in transverse section, outer edge acute; chambers numerous, closely appressed, planispiral in the early part, later chambers becoming uncoiled on the outer edge and tending to remain coiled at the inner edge; sutures flush, curved; surface smooth, finely perforate; apertural face broad, slightly convex with rather angled and projecting edges; aperture radiate, at the outer margin of the septal face, with about 12 to 14 teeth. Length of plesiotype, 0.82 mm.; thickness, 0.45 mm.; breadth in side view, 0.45 mm.

Plesiotype.—USC No. 608, sample L.

Genus VAGINULINA d'Orbigny, 1826
VAGINULINA PLUMMERAE (Cushman)
Plate 72, figures 15a, b

1926. *Cristellaria lineara*, CARSEY (not *C. linearis* d'Orbigny), Texas Univ. Bull. 2612, p. 36, pl. 2, fig. 3; Upper Cretaceous, Navarro group, Texas.
1931. *Hemicristellaria ensis*, PLUMMER (not Reuss), idem, Bull. 3101, p. 146, pl. 10, figs. 1–4; Upper Cretaceous, Austin, Taylor and Navarro, Texas.
1937. *Marginulina plummerae* CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 13, p. 97, pl. 13, figs. 21–23; Upper Cretaceous, Navarro (Corsicana marl), Texas.
1943. *Marginulina plummerae*, CUSHMAN & TODD, idem, Contr., vol. 19, p. 56, pl. 10, fig. 2; Upper Cretaceous, Navarro, Texas.
1946. *Marginulina plummerae*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 62, pl. 22, figs. 6–10; Upper Cretaceous, Navarro, Arkansas, Mississippi and Texas.
1949. *Marginulina plummerae*, CUSHMAN, idem., Prof. Paper 221-A, p. 5, pl. 2, fig. 12; Upper Cretaceous, Arkadelphia marl of the Navarro group, Arkansas.

Test elongate, straight to slightly curved, as much as six or seven times as long as broad, compressed throughout the early part, becoming ovate in section in the last few chambers, initial end with tendency to coil; chambers numerous, increasing gradually in size as added, closely appressed in the early portion, last few chambers somewhat inflated; sutures limbate, raised especially near the middle portion, slightly oblique and curved; wall smooth, finely perforate, ornamented only by the thickened raised sutures; aperture radiate, produced, at the outer peripheral angle, with about eight teeth. Length of plesiotype, 1.82 mm.; breadth of last chamber, 0.30 mm.; thickness of last chamber, 0.25 mm.

This species is more appropriately placed in the genus *Vaginulina* because it exhibits the flattened or compressed test throughout, only becoming ovate in the last few chambers in some specimens. *Marginulina* is round in transverse section throughout. There is a close relationship between this species and *Vaginulina cretacea* Plummer, the main difference being in the somewhat stronger sutural thickenings of the latter species and in the more inflated later chambers in the typical forms of *V. plummerae.*

Plesiotype.—USC No. 609, sample E.

Genus PLANULARIA Defrance, 1824

1824. *Planularia* DEFRANCE, Dict. Sci. Nat., vol. 32, p. 178.
1839. *Citharina* D'ORBIGNY, Hist. Phys. Pol. Nat. Cuba, Foram., p. XXXVII.

Test free, flattened, subtriangular in side view, early part curved but not making one volution, later portion evolute and broad; outer periphery smooth or variously ornamented; chambers numerous, the later ones rapidly increasing in breadth as added; sutures oblique and nearly parallel; wall finely perforate; aperture terminal radiate, on the outer curve of the test.

Included in this genus are many forms which are frequently misplaced under *Citharina* and *Vaginulina* d'Orbigny 1826. This genus differs from *Vaginulina* in the flat subtriangular test with chambers increasing rapidly in breadth as added. Many figures assigned to *Planularia* belong in genera such as *Robulus* and *Astacolus*. For excellent reproductions of the various types mentioned see Galloway's Manual of Foraminifera, 1933.

Genotype.—*Planularia auris* Defrance, 1824 (monotypic).

PLANULARIA MULTICOSTATA (Cushman)
Plate 72, figures 17a, b

1930. *Vaginulina multicostata* CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 6, p. 28, pl. 4, fig. 4; Prairie Bluff chalk, Navarro, Upper Cretaceous, Alabama.
1931. *Vaginulina simondsi*, CUSHMAN (part) (not Carsey), Tennessee Geol. Survey Bull. 41, pl. 4, figs. 7a, b; Upper Selma chalk, Navarro age, Upper Cretaceous, Tennessee.
1931. *Vaginulina simondsi*, CUSHMAN, Jour. Paleontology, vol. 5, p. 306, pl. 35, fig. 7; Saratoga chalk, Saratoga, Arkansas.
1943. *Vaginulina multicostata*, CUSHMAN & TODD, Cushman Lab. Foram. Research Contr., vol. 19, p. 58, pl. 10, fig. 19; Corsicana Marl, Navarro group, Upper Cretaceous, Texas.
1944. *Vaginulina multicostata*, CUSHMAN, idem, Contr., vol. 20, p. 88, pl. 13, fig. 13; Mooreville chalk, Selma group, Upper Cretaceous, Mississippi.
1944. *Vaginulina multicostata*, CUSHMAN & DEADERICK, Jour. Paleontology, vol. 18, p. 334, pl. 52, fig. 3; Marlbrook marl, Taylor, Upper Cretaceous, Texas.
1946. *Vaginulina multicostata*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 79, pl. 29, figs. 9–16; Navarro, Taylor and Austin of the Gulf Coastal region.
1949. *Vaginulina multicostata*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 254, pl. 23, fig. 5; Upper Cretaceous, Maryland.
1949. *Vaginulina multicostata*, CUSHMAN, U. S. Geol. Survey Prof. Paper 221–A, p. 6, pl. 2, fig. 24; Upper Cretaceous, Arkansas.

Test elongate, much compressed, dorsal edge straight, ventral edge strongly convex, pointed at both ends; chambers several, oblique, short and very broad, slightly curved, increasing in breadth very rapidly; sutures oblique, slightly limbate, curved downward on the ventral side of the test; wall ornamented with numerous fine costae, in general parallel to the straight dorsal edge of the test and mostly independent or not continuous from one chamber to the next; aperture terminal, on the dorsal side somewhat extended, radiate. Length of plesiotype, 1.70 mm.; breadth 0.37 mm.; thickness, 0.08 mm.

Plesiotype.—USC No. 598, sample E.

PLANULARIA NAVARROANA (Cushman)
Plate 72, figures 16a, b

1936. *Vaginulina navarroana* CUSHMAN, Geol. Soc. America Bull., vol. 47, p. 416, pl. 1, fig. 3; Upper Cretaceous (Navarro), Georges Bank.
1946. *Vaginulina navarroana*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 80, pl. 29, figs. 17–22; Upper Cretaceous (Navarro), Alabama, Arkansas, Mississippi and Texas. (See this reference for the complete synonymy to 1946.)
1949. *Vaginulina navarroana*, CUSHMAN, idem, Prof. Paper 221-A, p. 6, pl. 2, fig. 23; Upper Cretaceous, Arkansas.

Only one specimen was found which is referable to this species. The chambers extend well down toward the base and the sutures are slightly sigmoid.

Plesiotype.—USC No. 599, sample E.

Genus PALMULA Lea, 1833
PALMULA PRIMITIVA Cushman
Plate 72, figures 14a, b

1938. *Palmula simplex*, CUSHMAN (not Reuss), Cushman Lab. Foram. Research Contr., vol. 14, p. 36, pl. 6, fig. 1; Pecan Gap Chalk, Taylor marl, Upper Cretaceous, Texas.
1939. *Palmula primitiva* CUSHMAN, idem, Contr., vol. 15, p. 91, pl. 16, figs. 4, 5; Taylor formation, Upper Cretaceous, Texas.
1941. *Palmula primitiva*. CUSHMAN & HEDBERG, idem, Contr., vol. 17, p. 90, pl. 21, figs. 36, 37; upper part of Colon formation, Upper Cretaceous, Colombia, S. A.
1944. *Palmula primitiva*, CUSHMAN & DEADERICK, Jour. Paleontology, vol. 18, p. 335, pl. 52, fig. 6; Marlbrook marl, Taylor formation, Upper Cretaceous, Arkansas.
1946. *Palmula primitiva*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 84, pl. 32, figs. 1, 2; upper part of Taylor formation, Upper Cretaceous, Texas, Arkansas.

Test elongate, much compressed, edge subacute, sides in adult nearly parallel; early part planispiral for about one coil, then becoming uncoiled and rectilinear followed in adult specimens by equitant chambers; chambers distinct, narrowly limbate, flush; wall smooth, with slight tendency toward development of very fine indistinct longitudinal lines, especially near

the sutures; aperture terminal, radiate, Length of plesiotype, 0.75 mm.; breadth, 0.25 mm.; thickness, 0.07 mm.

This species is rather rare and only a few specimens exhibit a tendency toward the development of fine longitudinal striae.

Plesiotype.—USC No. 597, sample E.

Genus FRONDICULARIA Defrance, 1826

FRONDICULARIA ARCHIACIANA d'Orbigny

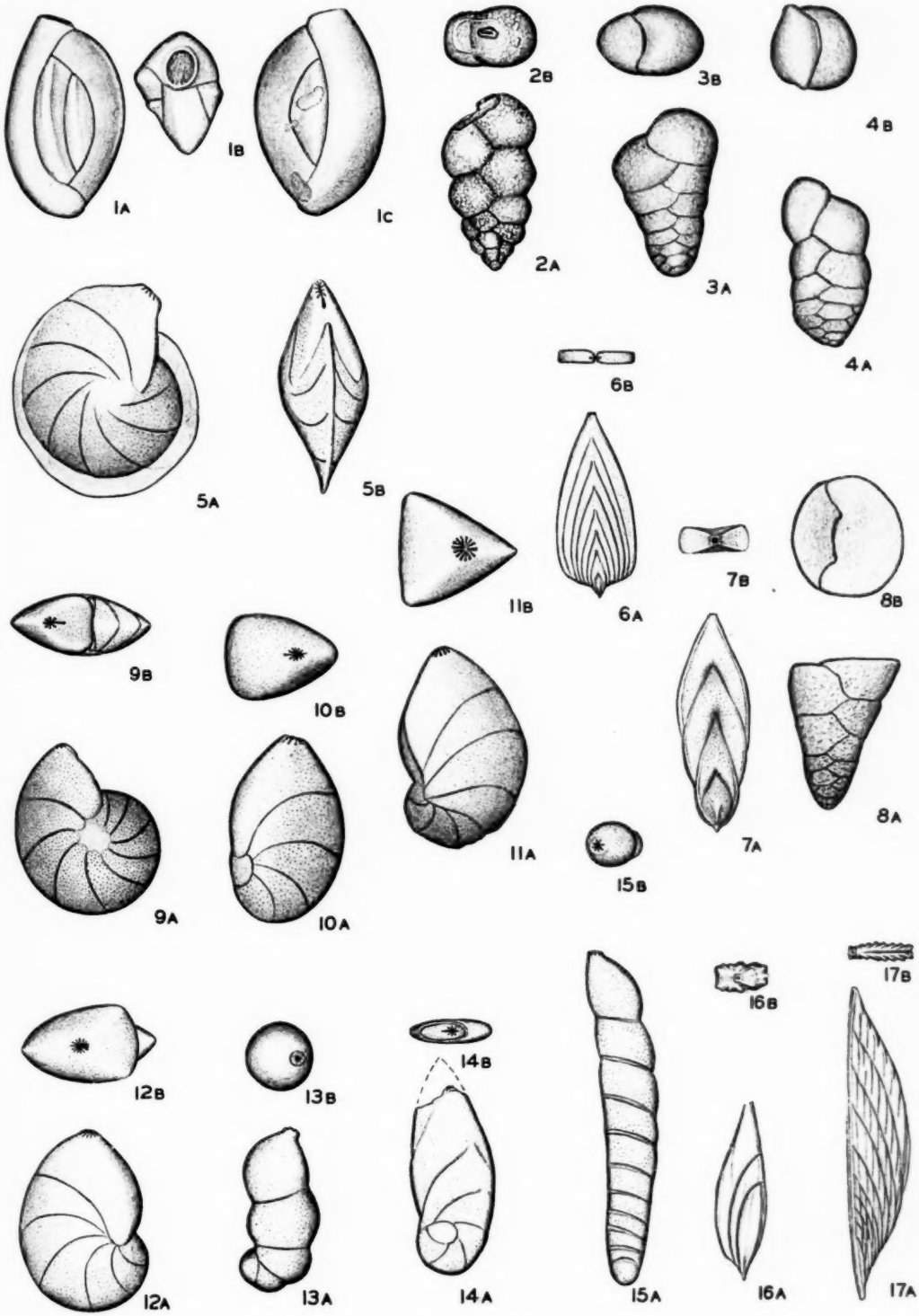
Plate 72, figures 7a, b

1840. *Frondicularia archiaciana* D'ORBIGNY, Soc. géol. France Mém., 1st. ser., vol. 4, p. 20, pl. 1, figs. 34–36; Upper Cretaceous, France.
1840. *Frondicularia angulosa* D'ORBIGNY, idem, Mém., 1st ser., vol. 4, p. 22, pl. 1, fig. 39.
1940. For references to 1940 see under each of above in Ellis and Messina, Catalogue of Foraminifera, Amer. Mus. Nat. History, New York, N. Y.
1943. *Frondicularia archiaciana*, CUSHMAN & TODD, Cushman Lab. Foram. Research Contr., vol. 19, p. 60, pl. 10, fig. 26; Upper Cretaceous (Taylor and Navarro formations), Texas.
1944. *Frondicularia archiaciana*, CUSHMAN & TODD, idem, Contr., vol. 20, p. 9, pl. 2, fig. 8; Upper Cretaceous (Pecan Gap Chalk, Taylor marl), Texas.
1946. *Frondicularia archiaciana*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 91, pl. 37, figs. 8–20; Upper Cretaceous (Taylor and Navarro formations), Texas, Tennessee, Arkansas, Mississippi.
1949. *Frondicularia archiaciana*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 255, pl. 23, fig. 10; Upper Cretaceous, Maryland.

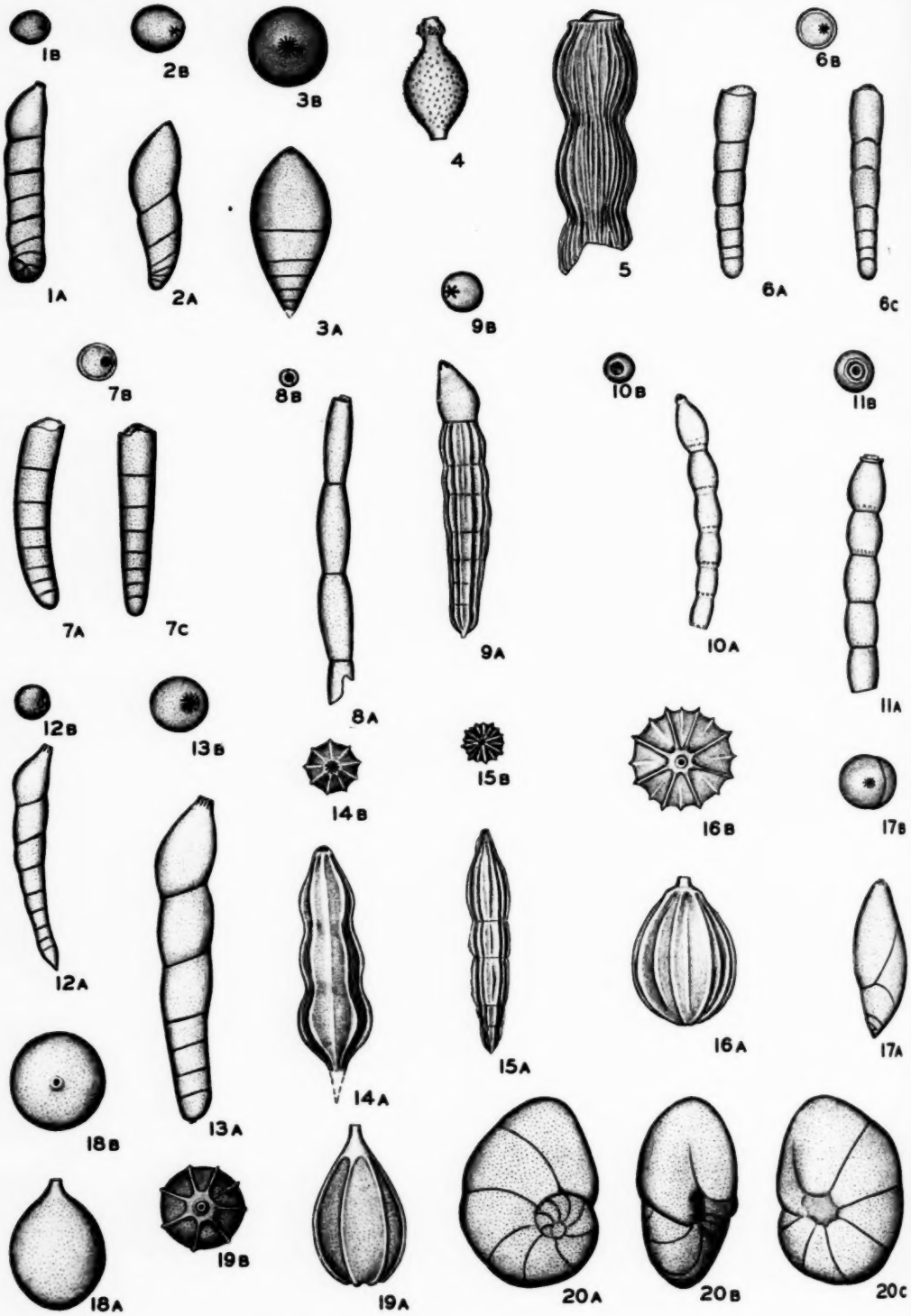
Test elongate, compressed, sides flattened, lanceolate, greatest breadth toward the apertural end; edge truncate, flat; periphery varying from slightly to moderately lobate; chambers varying from about two to 12 in number, uninflated, increasing gradually in size as added; proloculum rounded, apiculate, costate; sutures limbate and raised; wall calcareous, finely perforate, smooth excepting for the raised limbate sutures, apiculate apex, and the proloculum which bears from one to three longitudinal costae; aperture terminal, radiate. Length of plesiotype, 0.76 mm.; breadth, 0.29 mm.; thickness, 0.11 mm.

EXPLANATION OF PLATE 72

FIG. *1*—*Quinqueloculina* sp. ×50. *a*, Side view; *b*, apertural view; *c*, opposite side; plesiotype, USC No. 603. Sample E. (p. 491)
2—*Bermudezina extans* Bandy, n. sp. ×35. *a*, Side view; *b*, apertural view; holotype, USC No. 587. Sample E. (p. 492)
3—*Gaudryina arguta* Bandy, n. sp. ×50. *a*, Side view; *b*, apertural view; holotype, USC No. 578. Sample E. (p. 492)
4—*Dorothia bulletta* (Carsey). ×35. *a*, Side view; *b*, apertural view; plesiotype, USC No. 574. Sample L. (p. 491)
5—*Robulus pseudocultratus* Cole. ×35. *a*, Side view; *b*, edge view; plesiotype, USC No. 605. Sample L. (p. 493)
6—*Frondicularia goldfussi* Reuss. ×12. *a*, Side view; *b*, apertural view; plesiotype, USC No. 577. Sample E. (p. 497)
7—*Frondicularia archiaciana* d'Orbigny. ×35. *a*, Side view; *b*, apertural view; plesiotype, USC No. 576. Sample E. (p. 496)
8—*Marssonella oxycona* (Reuss). ×35. *a*, Side view; *b*, apertural view; plesiotype, USC No. 594. Sample E. (p. 492)
9—*Robulus modestus* Bandy, n. sp. ×35. *a*, Side view; *b*, edge view; holotype, USC No. 604. Sample E. (p. 493)
10—*Saracenaria subglobosa* Bandy, n. sp. ×50. *a*, Side view; *b*, apertural view; holotype, USC No. 607. Sample C. (p. 493)
11—*Saracenaria triangularis* (d'Orbigny). ×35. *a*, Side view; *b*, apertural view; plesiotype, USC No. 608. Sample L. (p. 494)
12—*Saracenaria navicula* (d'Orbigny). ×27. *a*, Side view; *b*, apertural view; plesiotype, USC No. 606. Sample E. (p. 493)
13—*Marginulina bullata* Reuss. ×35. *a*, Side view; *b*, apertural view; plesiotype, USC No. 591. Sample B. (p. 498)
14—*Palmula primitiva* Cushman. ×50. *a*, Side view; *b*, apertural view; plesiotype, USC No. 597. Sample E. (p. 495)
15—*Vaginulina plummerae* (Cushman). *a*, Side view; *b*, apertural view; plesiotype, USC No. 609. Sample E. (p. 494)
16—*Planularia navarroana* (Cushman). *a*, Side view; *b*, apertural view; plesiotype, USC No. 599. Sample E. (p. 495)
17—*Planularia multicostata* (Cushman). *a*, Side view; *b*, apertural view; plesiotype, USC No. 598. Sample E. (p. 495)



Bandy, Upper Cretaceous Foraminifera



Bandy, Upper Cretaceous Foraminifera

The intergradation between specimens with distinctly lobate to only slightly lobate periphery is continuous. Likewise there is variation between forms with only one longitudinal rib on the proloculum to those with two or three.

Plesiotype.—USC No. 576, sample E.

FRONDICULARIA GOLDFUSSI Reuss
Plate 72, figures 6a, b

1860. *Frondicularia goldfussi* REUSS, Akad. Wiss. Wien, Mathe.-naturwiss. Kl., Sitzungsber, vol. 40, p. 192, pl. 4, fig. 7; upper Senonian, Germany.

1946. *Frondicularia goldfussi*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, pp. 87–88, pl. 34, figs. 18–20; pl. 35, figs. 1, 2; Taylor formation, Austin formation, Gulf Coastal region, U. S.; Colon formation, Colombia. (For complete synonymy to 1946 see this reference.)

1949. *Frondicularia goldfussi*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 255, pl. 23, fig. 7; Upper Cretaceous, Maryland.

Test large, broad, much compressed with parallel sides, initial end blunt to angled in side view, the angle between the axis of the test and one side of the base varying from about 30° to 65°, apertural end slightly produced; edge truncate, flat; chambers about seven to ten in ephebic individuals, narrow, elongate, equitant, all chambers extending back to the base on either side; sutures flush, limbate, becoming progressively more curved; surface smooth except for the proloculum which is apiculate and which tends to have an elongate longitudinal rib; wall calcareous, finely perforate; aperture slightly produced, with about six radial teeth. Length of plesiotype, 2.28 mm.; breadth, 0.94 mm.; thickness, 0.14 mm.

These specimens seem identical in every

EXPLANATION OF PLATE 73

FIG. *1*—*Marginulina directa* Cushman. ×12. *a*, Side view; *b*, apertural view; plesiotype, USC No. 592. Sample L. (p. 498)

2—*Marginulina similis* d'Orbigny var. *obliquinodus* Bandy, n. var. ×35. *a*, Side view; *b*, apertural view; holotype, USC No. 593. Sample L. (p. 498)

3—*Glandulina* cf. *lagenoides* Olszewski. ×80. *a*, Side view; *b*, apertural view; plesiotype, USC No. 579. Sample C. (p. 499)

4—*Dentalina aculeata* d'Orbigny. ×27. Side view; plesiotype, USC No. 566. Sample L. (p. 499)

5—*Dentalina angusticostata* Cushman. ×27. Side view; plesiotype, USC No. 567. Sample L. (p. 499)

6—*Dentalina basiplanata* Cushman. ×50. *a*, Side view; *b*, apertural view; *c*, concave side; plesiotype, USC No. 568. Sample C. (p. 499)

7—*Dentalina megalopolitana* Reuss. ×50. *a*, Side view; *b*, apertural view; *c*, concave side, plesiotype, USC No. 569. Sample B. (p. 500)

8—*Dentalina* cf. *pseudofiliformis* Brotzen. ×27. *a*, Side view; *b*, end view; plesiotype, USC No. 570. Sample L. (p. 500)

9—*Dentalina marcki* Reuss. ×27. *a*, Side view; *b*, apertural view; plesiotype, USC No. 571. Sample C. (p. 500)

10—*Dentalina stephensoni* (Cushman). ×27. *a*, Side view; *b*, apertural view; plesiotype, USC No. 572. Sample L. (p. 501)

11—*Dentalina stephensoni* (Cushman). ×27. *a*, Side view; *b*, apertural view; plesiotype, USC No. 572a. Sample L. (p. 501)

12—*Dentalina wimani* Brotzen. ×27. *a*, Side view; *b*, apertural view; plesiotype, USC No. 573. and No. 573a. Sample L. (p. 501)

13—*Dentalina wimani* Brotzen. ×27. *a*, Side view; *b*, apertural view; plesiotype, USC No. 573a. Sample D. (p. 501)

14—*Nodosaria septemcostata* Geinitz. ×27. *a*, Side view; *b*, apertural view; plesiotype, USC No. 596. Sample E. (p. 502)

15—*Nodosaria amphioxys* Reuss. ×35. *a*, Side view; *b*, apertural view; plesiotype, USC No. 595. Sample L. (p. 501)

16—*Lagena acuticosta* Reuss var. *proboscidialis* Bandy, n. var. ×80. *a*, Side view; *b*, apertural view; holotype, USC No. 588. Sample E. (p. 503)

17—*Apiopterina apiculata* (Marie). ×35. *a*, Side view; *b*, apertural view; plesiotype, USC No. 559. Sample L. (p. 503)

18—*Lagena laevis* (Montagu) var. *stavensis* Bandy. ×80. *a*, Side view; *b*, apertural view; plesiotype, USC No. 589. Sample E. (p. 503)

19—*Lagena acuticosta* Reuss var. *brevipostica* Bandy, n. var. ×80. *a*, Side view; *b*, apertural view; holotype, USC No. 614. Sample L. (p. 502)

20—*Ceratobulimina cretacea* Cushman & Harris. ×80. *a*, Dorsal view; *b*, edge view; *c*, ventral view; plesiotype, USC No. 562. Sample E. (p. 507)

respect to Reuss' species. There is considerable variation in the angle between the axis of the test and one side of the base. Most of the individuals are close to the holotype in this respect; however, some exhibit a large angle and therefore a blunt base while others have a very small angle and a base which is more angular when viewed from the side. In the figured plesiotype the angle is about 67°.

Plesiotype.—USC No. 577, sample E.

Genus MARGINULINA d'Orbigny, 1826

MARGINULINA BULLATA Reuss

Plate 72, figures 13a, b

1845. *Marginulina bullata* REUSS, Verstein. böhm. Kreide-formation, pt. 1, p. 29, pl. 13, figs. 34–38.
1936. *Marginulina bullata*, BROTZEN, Sveriges geol. undersökning, Arsbok 30, no. 3, p. 62, pl. 4, fig. 1a–c; text-figure 19; lower Senonian, Sweden. See this reference for a complete synonymy to 1936.
1937. *Marginulina bullata*, CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 13, p. 96, pl. 14, figs. 9–15.
1944. *Marginulina bullata*, CUSHMAN, idem, Contr., vol. 20, p. 6, pl. 1, fig. 21.
1946. *Marginulina bullata*, CUSHMAN, U. S. Geological Survey Prof. Paper 206, p. 62, pl. 21, figs. 32–37; Upper Cretaceous (Taylor and lower Navarro), Gulf Coastal area.
1949. *Marginulina bullata*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 250, pl. 22, fig. 1; Upper Cretaceous, Maryland.

Test elongate, circular in cross-section, early portion coiled, later portion uncoiled; chambers slightly inflated at first, then become gradually more inflated toward the apertural end; sutures of the early portion flush, radial, those of the later portion depressed nearly transverse and then becoming oblique toward the apertural end; wall calcareous, finely perforate, smooth; aperture radiate at the end of a short distinct neck at the outer peripheral edge of the last chamber. Length of plesiotype, 0.66 mm.; diameter, 0.28 mm.

The cylindrical neck is characteristic of this species.

Plesiotype.—USC No. 591, sample B.

MARGINULINA DIRECTA Cushman

Plate 73, figures 1a, b

1937. *Marginulina austinana* var. *directa* CUSHMAN, Cushman Lab. Foram. Res. Contr., vol. 13, p. 93, pl. 13, figs. 5–8; Austin chalk, Upper Cretaceous, Texas.
1946. *Marginulina austinana* var. *directa*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 59, pl. 20, figs. 11–16; Taylor marl (Wolfe City sand member), Austin chalk, Upper Cretaceous, Texas.

Test elongate, early part coiled and slightly compressed with angled back, later portion uncoiled, rectilinear with parallel sides and oval to circular in section; chambers distinct, increasing gradually in size in the coiled portion, about four to eight of nearly equal size form the uncoiled part and become somewhat inflated toward the apertural end; sutures flush and slightly curved in the coiled portion, in the uncoiled section they are nearly transverse, somewhat limbate and become depressed toward the apertural end; wall calcareous, finely perforate, smooth; aperture terminal, radiate, with about eight radial teeth located at the outer peripheral angle. Length of plesiotype, 2.42 mm.; breadth of last chamber, 0.47 mm.; thickness of last chamber, 0.42 mm.

Plesiotype.—USC No. 592, sample L.

MARGINULINA SIMILIS d'Orbigny var. OBLIQUINODUS Bandy, n. var.

Plate 73, figures 2a, b

Test elongate, tapered, nearly circular in cross-section, early portion slightly curved; chambers closely appressed, uninflated, with a tendency to coil in the early part, later portion rectilinear, early chambers short, later chambers lengthen rapidly; sutures flush, in the early part radial, those in the later portion oblique; surface smooth, wall calcareous, finely perforate; aperture terminal, eccentric, located toward the outer periphery, radiate, with about six teeth. Length of holotype, 0.58 mm.; diameter, 0.20 mm.

Marginulina similis d'Orbigny [1846, Foraminiféres du bassin tertiaire de Vienne (Autriche), Gide et Cie., Paris, p. 69, pl. 3, figs. 15–16] differs in having more inflated chambers and a more centrally located aperture. The distinctive features of this variety consist of a tapered test with little curvature, closely appressed uninflated chambers rapidly increasing in height with growth, oblique sutures which are flush with the surface, and eccentric aperture.

Holotype.—USC No. 593, sample L.

Genus GLANDULINA d'Orbigny, 1839
GLANDULINA cf. LAGENOIDES Olszewski
Plate 73, figures 3a, b

1875. *Glandulina lagenoides* OLSZEWSKI, Sprawozd. Kom. Fizyj. Akad. Umiej., Krakowie, vol. 9, p. 107, pl. 1, fig. 6.
1931. *Pseudoglandulina* sp., PLUMMER, Texas Univ. Bull. 3101, p. 158, pl. 10, figs. 16, 17; Navarro formation, Texas.
1946. *Pseudoglandulina lagenoides* CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 76, pl. 27, fig. 29; Upper Cretaceous. (For additional synonymy to 1946 see this reference.)
1949. *Pseudoglandulina lagenoides* CUSHMAN, idem, Prof. Paper 221-A, p. 5, pl. 2, fig. 22; Upper Cretaceous, Arkansas.

Test elongate elliptical with the greatest width near the apertural end; chambers six to about eight or nine in number, much overlapping, the last chamber occupying about one-fourth to one-third of the test; sutures transverse, flush, sometimes the last one is very slightly depressed; wall calcareous, finely perforate, initial end sometimes apiculate; aperture terminal, radiate, about 15 radial teeth. Length of plesiotype, 0.31 mm.; diameter, 0.15 mm.

The figured specimen agrees with that of Plummer (see synonymy) but some of the individuals are much more elongate. This species is very rare in the materials of this study.

Plesiotype.—USC No. 579, sample C.

Genus DENTALINA d'Orbigny, 1839
DENTALINA ACULEATA d'Orbigny
Plate 73, figure 4

1840. *Nodosaria (Dentalina) aculeata* D'ORBIGNY, Soc. géol. France Mém., 1st. ser., vol. 4, p. 13, pl. 1, figs. 2, 3; Cretaceous, Senonian, Paris Basin.
1946. *Dentalina aculeata* CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 67, pl. 26, figs. 17, 18; Taylor marl, Upper Cretaceous, Texas. (For complete synonymy see this reference and the Catalogue of Foraminifera, Ellis and Messina, Am. Mus. Nat. History, 1940 et seq.)

Only a few incomplete specimens were found which are assignable to this species.

Plesiotype.—USC No. 566, sample L.

DENTALINA ANGUSTICOSTATA Cushman
Plate 73, figure 5

1938. *Dentalina angusticostata* CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 14, p. 41, pl. 6, figs. 21, 22; Upper Cretaceous, (Corsicana marl of the Navarro group), Texas.
1940. *Dentalina angusticostata*, CUSHMAN, idem, Contr., vol. 16, p. 85, pl. 14, figs. 7, 8; same age and locality as above.
1943. *Dentalina angusticostata*, CUSHMAN & TODD, idem, Contr., vol. 19, p. 57, pl. 10, fig. 10; same age and locality as above.
1946. *Dentalina angusticostata*, CUSHMAN, U. S. Geol. Survey, Prof. Paper 206, p. 70, pl. 24, figs. 7, 8; Upper Cretaceous (Corsicana marl of Navarro age), Texas.

Test large, elongate, slightly curved, very gradually tapering; chambers numerous, inflated, somewhat fusiform, longer than broad, increasing very gradually in size as added; sutures depressed, somewhat limbate; wall covered with numerous fine high longitudinal costae which are mostly continuous across the sutures, some of the costae anastomose and branch occasionally; aperture terminal, eccentric, radiate, somewhat projecting. Length of the last two chambers of the plesiotype, 1.10 mm.; diameter, 0.45 mm.

Only a few broken fragments of this large *Dentalina* were found. They resemble the paratype (Cushman, 1940, fig. 8) of this species rather closely.

Plesiotype.—USC No. 567, sample L.

DENTALINA BASIPLANATA Cushman
Plate 73, figures 6a–c

1931. *Dentalina annulata*, CUSHMAN (not Reuss), Tennessee Geol. Survey Bull. 41, p. 28, pl. 3, fig. 3; Upper Cretaceous, Tennessee.
1931. *Dentalina reussi*, PLUMMER (not Neugeboren), Texas Univ. Bull. 3101, p. 151, pl. 11, fig. 5; Upper Cretaceous (Taylor and Navarro), Texas.
1932. *Dentalina reussi*, SANDIDGE, Jour. Paleontology, vol. 6, p. 274, pl. 42, fig. 10; Upper Cretaceous (Ripley formation), Alabama.
1938. *Dentalina basiplanata* CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 14, p. 38, pl. 6, figs. 6–8; Upper Cretaceous (Navarro and upper Taylor), Texas.
1946. *Dentalina basiplanata*, CUSHMAN, U. S. Geol. Survey, Prof. Paper 206, p. 68, pl. 24, figs. 9–12; Upper Cretaceous, southeastern United States.
1946. *Dentalina basiplanata*, CUSHMAN & RENZ, Cushman Lab. Foram. Research Special Pub. 18, p. 28, pl. 4, figs. 12, 13; Upper Cretaceous of Trinidad, Colombia, Mexico and United States.
1946. *Dentalina basiplanata*, SCHIJFSMA, Meded. van de Geologische Stichting, ser. c-v, no. 7, p. 42, pl. 2, fig. 12; Campanian, southern Limburg.

1949. *Dentalina basiplanata*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 251, pl. 22, fig. 12; Upper Cretaceous, Maryland. (Publication dated 1948 but issued in January, 1949.)
1949. *Dentalina basiplanata*, CUSHMAN, U. S. Geol. Survey Prof. Paper 221-A, p. 5, pl. 2, fig. 17; Upper Cretaceous (Arkadelphia marl of the Navarro), Arkansas.

Test elongate, slightly arcuate and tapering, initial end rounded; chambers in the early part shorter than broad, then becoming gradually longer until the last few chambers have a ratio of length to diameter of nearly 3:2, early chambers closely appressed, later chambers somewhat inflated; sutures nearly transverse, sometimes slightly oblique in the early portion, narrowly limbate; aperture terminal, eccentric, located near the concave edge of the last chamber. Length of plesiotype, 0.57 mm.; diameter of the last chamber, 0.11 mm.

Plesiotype.—USC No. 568, sample C.

DENTALINA MARCKI Reuss
Plate 73, figures 9a, b

1860. *Dentalina marcki* REUSS, Akad. Wiss. Wien Sitzungsbericht, vol. 40, pp. 188. 189, pl. 2, fig. 7; upper Senonian, Germany.
1936. *Dentalina marcki*, BROTZEN, Sveriges geol. undersökning, Arsbok 30, no. 3, p. 80, pl. 5, fig. 27; lower Senonian, Sweden. (For a complete synonymy to this date see this reference.)
1946. *Dentalina marcki*, SCHIJFSMA, Meded. van de Geologische Stichting, ser. C–V, no. 7, p. 44, pl. 2, figs. 5–7; upper Senonian (Campanian), Southern Limburg.

Test large, slightly arcuate and tapering, initial end with prominent spine; chambers numerous, closely appressed in the later part, broader than high in the early part, becoming slightly higher than broad in the adult portion; sutures straight, transverse to the axis of the test, flush in the early part, later somewhat depressed; wall ornamented by about ten to 14 longitudinal costae which are continuous across the sutures, last chamber usually smooth or nearly so; aperture terminal, produced, radiate, near the concave side of the test. Length of plesiotype, 1.52 mm.; diameter, 0.22 mm.

None of the specimens examined exhibit the alternating ribbing or costae characteristic of *D. alternata* (Jones).

Plesiotype.—USC No. 571, sample C.

DENTALINA MEGALOPOLITANA Reuss
Plate 73, figures 7a–c

1855. *Dentalina megalopolitana* REUSS, Deutsche geol. Gesell. Zeitschr., vol. 7, p. 267, pl. 8, fig. 10; Turonian, Upper Cretaceous, Germany.
1946. *Dentalina megalopolitana*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 67, pl. 23, figs. 24–26; Upper Cretaceous, southeastern United States. (See this reference for complete synonymy to 1946.)
1946. *Dentalina megalopolitana*, CUSHMAN & RENZ, Cushman Lab. Foram. Research Special Pub. 18, p. 28, pl. 4, fig. 11; Upper Cretaceous, Trinidad, Velasco shale of Mexico, and in the Upper Cretaceous (Taylor and Navarro) of the southern United States.
1949. *Dentalina megalopolitana*, CUSHMAN, Maryland Dept. of Geology, Mines and Water Resources Bull. 2, p. 251, pl. 22, fig. 10; Upper Cretaceous, Maryland.

Test slightly arcuate, gently tapering in the early part, sides nearly parallel in adult; chambers about eight to ten in number, closely appressed; sutures flush, nearly transverse to axis of test, limbate and straight; wall smooth, finely perforate; aperture terminal near the inner edge of the last chamber, radiate. Length of plesiotype, 0.56 mm.; diameter, 0.11 mm.

The apex is not apiculate in the few California forms referred to in this study, otherwise there is no difference between these and the European forms.

Plesiotype.—USC No. 569, sample B.

DENTALINA cf. PSEUDOFILIFORMIS Brotzen
Plate 73, figures 8a, b

1936. *Dentalina pseudofiliformis* BROTZEN, Sveriges geol. undersökning, Arsbok 30, no. 3, Stockholm, p. 77, pl. 5, figs. 3–5; lower Senonian, Sweden.
1946. *Dentalina* cf. *D. consobrina* CUSHMAN (not d'ORBIGNY), U. S. Geol. Survey Prof. Paper 206, p. 69, pl. 24, figs. 23–27; see this reference for listings of other forms which may belong hereunder.

Test elongate, slender, slightly arcuate, tapering very gradually to the apiculate initial end; chambers numerous, at first about as long as broad, becoming rapidly longer, in the later chambers about three times longer than broad and slightly barrel-shaped; sutures transverse and almost flush in the early portion, becoming slightly depressed in the later part, occasionally the

sutures are somewhat limbate. Length of plesiotype, 1.55 mm.; breadth, 0.19 mm.

Several broken fragments of this form occur in the material studied. As indicated by Brotzen this species is very near *D. boueana* d'Orbigny (1846, Tertiary of the Vienna Basin) differing mainly in the less depressed sutures. The differences mentioned in the type description are hardly more than individual variation.

Plesiotype.—USC No. 570, sample L.

DENTALINA STEPHENSONI (Cushman)
Plate 73, figures 10a, b, 11a, b

1936. *Ellipsonodosaria stephensoni* CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 12, p. 52, pl. 9, figs. 10–15; Taylor marl, Upper Cretaceous, Texas.
1943. *Ellipsonodosaria stephensoni*, CUSHMAN & TODD, idem, Contr., vol. 19, p. 67, pl. 11, fig. 28; Corsicana marl, Navarro group, Upper Cretaceous, Texas.
1944. *Ellipsonodosaria stephensoni*, CUSHMAN, idem, Contr., vol. 20, p. 94, pl. 13, figs. 31, 32; Mooreville chalk, Selma group, Upper Cretaceous, Mississippi.
1944. *Ellipsonodosaria stephensoni*, CUSHMAN & DEADERICK, Jour. Paleontology, vol. 18, p. 338, pl. 53, figs. 14–16; Marlbrook marl, Taylor, Upper Cretaceous, Texas.
1946. *Ellipsonodosaria stephensoni*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 134, pl. 56, figs. 2–7; Navarro, Taylor and Austin, of Texas, Tennessee, Mississippi and Arkansas.
1949. *Ellipsonodosaria stephensoni*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 263, pl. 25, fig. 11; Upper Cretaceous, Maryland.
1949. *Ellipsonodosaria stephensoni*, CUSHMAN, U. S. Geol. Survey Prof. Paper 221-A, p. 9, pl. 4, fig. 10; Upper Cretaceous, Arkansas.

Test elongate, slightly arcuate; chambers numerous, increasing rather rapidly in diameter in the early portion of the test, more slowly in the later part; increase in chamber length is rather rapid throughout; sutures transverse, depressed throughout, slightly limbate; wall smooth excepting for a ring of short, backwardly projecting spines near the base of each chamber, occasionally with a few additional scattered spines on the last few chambers; aperture terminal, produced, circular. Length, 1.3 mm.; diameter, 0.16 mm.

Numerous specimens were examined in order to determine the character of the aperture but a definite tooth was found in none. In sample L at the top of the section two specimens with complete apertures have cylindrical necks and complexly radiate apertures.

Plesiotype.—USC No. 572, sample L.

DENTALINA WIMANI Brotzen
Plate 73, figures 12a, b, 13a, b

1936. *Dentalina wimani* BROTZEN, Sveriges geol. undersöckning Afh., ser. C, no. 396 (Arsbok 30, no. 3), p. 76, pl. 5, figs. 15, 16; lower Senonian, Sweden.

Test elongate, slightly arcuate, initial end with a strong spine; initial chamber larger than the immediately succeeding chambers, early chambers shorter than broad, later chambers becoming about as long as broad and the last few are longer than broad; periphery slightly lobulate, more so on the convex side than on the inner side; sutures flush in the early part, depressed in the later portion, slightly irregular, usually nearly transverse in the early portion, becoming oblique in the later part of the test; aperture terminal, near the inner margin, produced and radiate with about six or seven radial teeth. Length of plesiotype, 1.25 mm.; diameter of last chamber, 0.20 mm.

Brotzen's types apparently have a greater number of radial teeth, otherwise the specimens are alike. Many forms with rather oblique sutures and apiculate apices assigned to *Dentalina gracilis* d'Orbigny should most likely be placed in this species.

Plesiotype.—USC No. 573 and 573a, samples L and D, respectively.

Genus NODOSARIA Lamarck, 1812

NODOSARIA AMPHIOXYS Reuss
Plate 73, figures 15a, b

1875. *Nodosaria amphioxys* REUSS, Palaeontographica, vol. 20, pt. 2, p. 82, pl. 2 (20), fig. 8, 1875.
1946. *Nodosaria amphioxys*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 72, pl. 26, fig. 14; Upper Cretaceous (Taylor and Navarro) Gulf Coast. See this reference for synonymy to 1946.

Test slender, cylindrical, elongate, pointed at both ends, initial end sometimes apiculate; chambers slightly inflated, increasing rapidly in length as added, about five to seven in number; sutures slightly depressed, transverse to the axis of the test; surface

ornamented with several continuous and prominent longitudinal costae, about four or five extending from end to end, secondary intercalated costae somewhat less continuous; apertural end produced; aperture terminal, radiate (?). Length of plesiotype, 0.89 mm.; diameter, 0.18 mm.

Plesiotype.—USC No. 595, sample L.

NODOSARIA SEPTEMCOSTATA Geinitz
Plate 73, figures 14a, b

1842. *Nodosaria septemcostata* GEINITZ, Charakteristik der Schichten und Petrefacten des sächsisch-böhmischen Kreidegebirges. Leipzig, Deutschland, Arnold, Heft 3, pp. V, 69, pl. 17, fig. 20; Upper Cretaceous, Bohemia.
1842. *Nodosaria undecimcostata* GEINITZ, idem, pp. V, 69, pl. 17, fig. 19a, b; same locality and age.
1844. *Nodosaria zippei* REUSS, Geognostische Skizzen aus Böhman; II-Die Kreidegebilde des Westlichen Böhmens, ein monographischer Versuch. C. W. Medau, Prag, Österreich, vol. 2, p. 210; Upper Cretaceous, Bohemia.
1936. *Nodosaria zippei*, BROTZEN, Sveriges geol. undersökning, Arsbok 30, no. 3, pp. 82–84, pl. 5, fig. 12; lower Senonian, Sweden. (See this reference for a complete synonymy to 1936.)
1936. *Nodosaria affinis* CUSHMAN, Geol. Soc. America Bull., vol. 47, p. 417.
1940. *Nodosaria affinis*, CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 16, p. 86, pl. 15, figs. 8–23; Upper Cretaceous, southeastern United States and Trinidad.
1943. *Nodosaria affinis*, CUSHMAN & TODD, idem, Contr., vol. 19, p. 57, pl. 10, fig. 11; Upper Cretaceous (Corsicana marl of Navarro age), Texas.
1944. *Nodosaria affinis*, CUSHMAN, idem, Contr., vol. 20, pp. 7, 87, pl. 2, fig. 1, pl. 13, fig. 18; Upper Cretaceous, Texas and Mississippi.
1944. *Nodosaria affinis* CUSHMAN & DEADERICK, Jour. Paleontology, vol. 18, p. 333, pl. 51, figs. 19–21; Upper Cretaceous (Marlbrook marl of Taylor age), Texas.
1946. *Nodosaria affinis*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206; pp. 7–71; pl. 25, figs. 8–23; Upper Cretaceous, southeastern United States.
1946. *Nodosaria affinis*, CUSHMAN & RENZ, Cushman Lab. Foram. Research Special Pub. 18, p. 30, pl. 5, fig. 1; Upper Cretaceous, Trinidad.
1949. *Nodosaria affinis*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 252, pl. 22, fig. 23; Upper Cretaceous, Maryland.
1949. *Nodosaria affinis*, CUSHMAN, U. S. Geol. Survey Prof. Paper 221-A, p. 5, pl. 2, fig. 20; Upper Cretaceous (Arkadelphia marl of Navarro age), Arkansas.

Test large, elongate; microspheric form tapering, with many chambers; megalospheric form with nearly equal chambers excepting the initial one which may be somewhat larger; chambers distinct, inflated throughout, usually more so toward the apertural end; sutures transverse, depressed; wall ornamented by numerous (seven to 14) longitudinal, continuous costae, initial chamber equipped with a prominent spine; aperture terminal, central, produced, radiate with about 12 to 14 radial teeth. Length of plesiotype, 1.22 mm.; diameter of last chamber, 0.32 mm.

According to Article 28 in the Rules of Zoological Nomenclature, a species formed by the union of two or more species takes the oldest valid generic name of its components. If the names are of the same date, that selected by the first reviser shall stand. Reuss (1844, in synonymy above) recognized the similarity of *N. septemcostata* and *N. undecimcostata* of Geinitz, 1842, but he brought them together under the name *N. zippei* in 1844. One of Geinitz's specific names should be designated, however, and *N. septemcostata* is chosen because it precedes *N. undecimcostata* on page 69 of the original reference.

Plesiotype.—USC No. 596, sample E.

Genus LAGENA Walker & Boys, 1784
LAGENA ACUTICOSTA Reuss var. BREVIPOSTICA Bandy, n. var.
Plate 73, figures 19a, b

Test ovate in side view, circular in end view; base rounded; apertural end with a shoulder and a short cylindrical neck; surface ornamented with about six to nine costae which blend into the shoulder at the apertural end and extend almost to the outer end, then enlarging and passing gradually into the base; aperture a simple tubular opening without lip. Length of holotype, 0.29 mm.; diameter, 0.16 mm.

This variety is represented by several specimens and seems to be quite consistent in its characters. It differs from the typical form (Reuss, K. Akad. Wiss. Wien, Math.-Naturw. Cl., Sitzber., Wien, 1862, Bd. 44, Abth. 1, p. 305, pl. 1, fig. 4) in the fewer costae and in the long smooth shoulder.

Holotype.—USC No. 614, sample L.

LAGENA ACUTICOSTA Reuss var.
PROBOSCIDIALIS Bandy, n. var.
Plate 73, figures 16a, b

Test ovate in side view, circular in end view; base rounded; apertural end with a shoulder and short cylindrical neck; surface ornamented with about 18 to 20 costae which blend into the shoulder at the apertural end and extend to the basal apex at the other end; in all forms there are intercalated costae which are shorter, terminating before reaching the base and shoulder; neck short, cylindrical, smooth, without lip. Length of holotype, 0.27 mm.; diameter, 0.19 mm.

This form varies from ovate to elongate ovate or elliptical in side view. The characteristic elliptical or more ovate shape separates it from the typical variety. The forms figured by Brotzen (1936, Sveriges geol. undersökning, Arsbok 30, no. 3) probably belong here. *Lagena isabella*, (d'Orbigny) lacks the shoulder and has a longer neck.

Holotype.—USC No. 588, sample E.

LAGENA LAEVIS (Montagu) var.
STAVENSIS Bandy
Plate 73, figures 18a, b

1942. *Lagena laevis* var. BERGQUIST (not Montagu), Mississippi Geol. Survey Bull. 49 (Fossils), p. 51, pl. 5, fig. 7; upper Eocene, Mississippi.
1946. *Lagena* cf. *L. globosa*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 95, pl. 39, fig. 26; Upper Cretaceous, Alabama, Arkansas Tennessee, Texas, Mexico.
1949. *Lagena laevis* (Montagu) var. *stavensis* BANDY, Bull. Am. Paleontology, vol. 32, no. 131, p. 56, pl. 7, figs. 15a–b; Jackson formation, upper Eocene, Alabama.

Test globular, ovoid, widest just below the middle, circular in cross-section; base rounded, smooth; neck short, round, tapering, about one-seventh the length of the body; wall smooth, finely perforate; aperture round, without lip, at the end of the short tapering neck. Length of plesiotype, 0.23 mm.; diameter, 0.17 mm.

The neck is smaller and more definite in this variety than in *L. globosa* (Montagu) (1803, Tert. Brit., p. 523). *L. laevis* (Montagu) is more elongate than this variety.

Plesiotype.—USC No. 589, sample E.

Family POLYMORPHINIDAE d'Orbigny, 1846
Genus APIOPTERINA Zborzewski, 1834
APIOPTERINA APICULATA (Marie)
Plate 73, figures 17a, b

1941. *Pyrulina cylindroides* (ROEMER) var. *apiculata* MARIE, Paris, Mus. Nat. histoire nat. Mém., n. s., vol. 12, part 1, p. 175, pl. 27, figs. 257–258; Upper Cretaceous (Campanian), Paris basin.

Test irregular fusiform, about three times longer than wide, pointed at both ends; oval in section; chambers numerous, somewhat embracing, about four or five to the whorl in the early portion, then reducing rapidly to two to the whorl in the adult portion; sutures nearly flush throughout; surface smooth, finely perforate; aperture terminal, radiate with about ten to 12 teeth. Length of plesiotype, 0.65 mm.; breadth, 0.25 mm.; thickness, 0.22 mm.

Plesiotype.—USC No. 559, sample L.

Family ROTALIIDAE Reuss, 1860
Genus VALVULINERIA Cushman, 1926
VALVULINERIA ALLOMORPHINOIDES
(Reuss)
Plate 74, figures 4a–c

1860. *Valvulina allomorphinoides* REUSS, Akad, Wiss. Wien, Math.-naturwiss. Kl., Sitzungsber., vol. 40, p. 223, pl. 11, figs. 6a–c; Upper Cretaceous, Europe.
1946. *Valvulineria allomorphinoides*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 138, pl. 57, figs. 6, 7; Senonian of Europe; Upper Cretaceous, Austin, Taylor and Navarro of the Gulf Coastal area, U. S. (See this paper for complete synonymy to 1946.)
1946. *Valvulineria allomorphinoides*, CUSHMAN & RENZ, Cushman Lab. Foram. Research Special Pub. 18, p. 44, pl. 7, figs. 13, 14; Upper Cretaceous (lower zone of Lizard Springs marl), Trinidad.
1949. *Valvulineria allomorphinoides*, CUSHMAN, Maryland Dept. of Geology, Mines and Water Resources Bull. 2, p. 263, pl. 25, fig. 12; Upper Cretaceous, Maryland.

Test rather small, slightly longer than broad, rotaloid, biconvex; periphery lobulate; edge rounded; chambers few, from four to five in the final whorl, inflated ventrally with a distinct valvular lip extending out over the umbilicus; ventral sutures somewhat depressed and nearly radial, dorsal sutures only slightly depressed, gently curved and slightly oblique; wall smooth, finely perforate; aperture a low

opening in the umbilicus under the overhanging lip of the last chamber. Length of plesiotype, 0.51 mm.; breadth, 0.43 mm.; thickness, 0.25 mm.

The average number of chambers in the last whorl of the specimens studied is four. The figured specimen is a large individual with about four and one-half chambers.

Plesiotype.—USC No. 610, sample E.

VALVULINERIA CRETACEA (Carsey)
Plate 74, figures 1a–c

1926. *Rotalia cretacea* CARSEY, Texas Univ. Bull. 2612, p. 48, pl. 5, figs. 1a, b; Upper Cretaceous (characteristic of Navarro), Texas.
1932. *Rotalia cretacea*, SANDIDGE, Am. Midland Naturalist, vol. 13, p. 364, pl. 33, figs. 7, 8; Upper Cretaceous (Ripley formation), Alabama.
1943. *Valvulineria cretacea*, CUSHMAN & TODD, Cushman Lab. Foram. Research Contr., vol. 19, p. 67, pl. 12, fig. 1; Upper Cretaceous (Navarro), Texas.
1946. *Valvulineria cretacea*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 138, pl. 57, fig. 8; Upper Cretaceous (characteristic of Navarro, occasionally in Taylor beds), Texas, Mississippi and Arkansas.

Test biconvex, rotaloid, dorsal side moderately convex, ventral side moderately to strongly convex; edge acute to very abruptly rounded; periphery smooth, only slightly if at all lobulate; chambers nine to about 12 in the final whorl, closely appressed, increasing very gradually in size as added, the last chamber with a rounded valvular flap covering the umbilicus; ventral sutures flush, straight, radial, dorsal sutures flush, nearly radial, both ends curved backward; wall smooth; finely perforate; aperture a narrow elongate slit along the base of the last septal face extending under the valvular flap covering the umbilicus. Diameter of holotype, 0.38 mm.; thickness, 0.21 mm.

Plesiotype.—USC No. 612, sample L.

VALVULINERIA NONIONOIDES Bandy, n. sp.
Plate 74, figures 5a–c

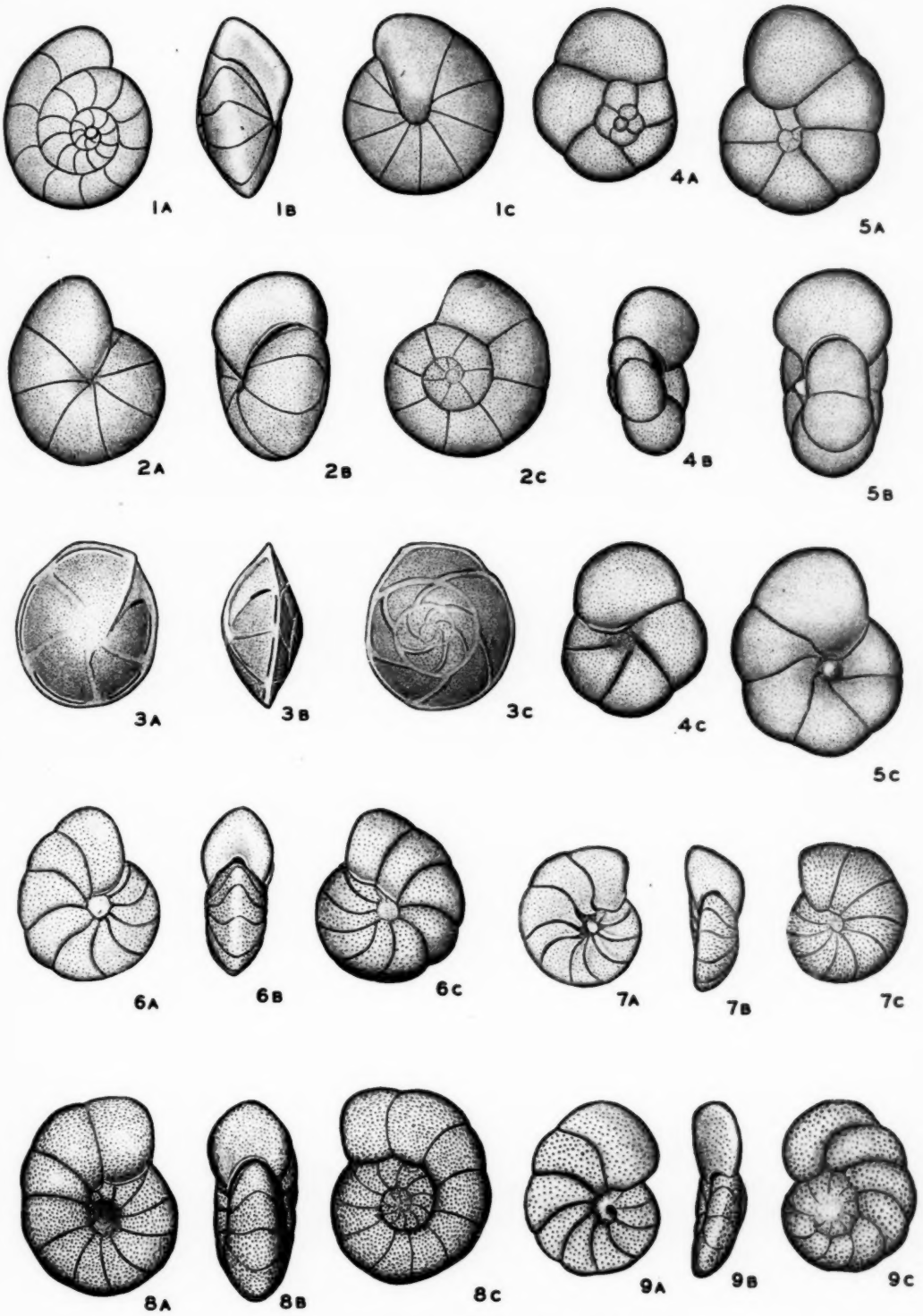
1931. *Valvulineria* cf. *V. umbilicatula*, CUSHMAN, (not d'Orbigny), Tennessee Geol. Survey Bull. 41, p. 53, pl. 9, fig. 5 (not 2–4); Upper Cretaceous (Selma chalk), Tennessee.
1944. *Valvulineria* cf. *V. umbilicatula*, CUSHMAN & DEADERICK (not d'Orbigny), Jour. Paleontology, vol. 18, p. 339, pl. 53, figs. 17, 18; Upper Cretaceous (Marlbrook marl, Taylor group), Arkansas.

Test subcircular in outline, rotaloid, nearly bilaterally symmetrical but the ventral side somewhat more convex; edge broadly rounded throughout the last whorl; periphery somewhat lobulate; ventral side strongly umbilicate with a rather prominent central tubercle; dorsal side with broad shallow umbilicus; chambers about five or six, increasing very gradually in size as added; sutures radial, nearly straight, slightly recurved in the ventral umbilicus, moderately depressed throughout; wall smooth, finely perforate, no ornamentation excepting the prominent ventral plug; aperture an elongate slit extending from the edge to the ventral plug under the umbilical flap of the last chamber. Diameter of holotype, 0.38 mm.; thickness of last chamber, 0.22 mm.

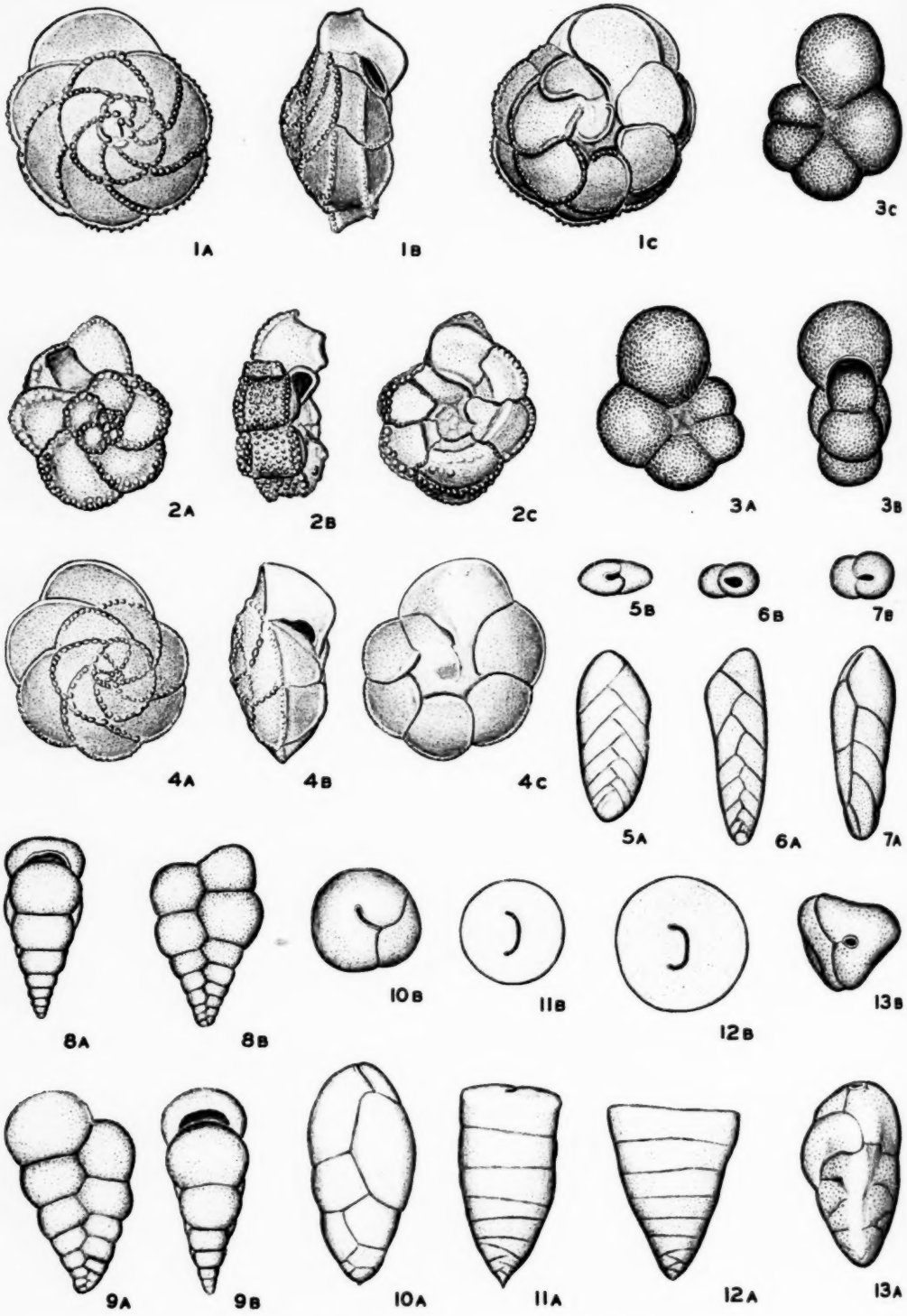
The umbilical tubercle or plug and the nearly bilateral symmetry are diagnostic

EXPLANATION OF PLATE 74

FIG. *1*—*Valvulineria cretacea* (Carsey). ×70. *a*, Dorsal view; *b*, edge view; *c*, ventral view; plesiotype, USC No. 612. Sample L. (p. 504)
2—*Gyroidina globosa* (Hagenow) var. *orbicella* Bandy, n. var. ×120. *a*, Ventral view; *b*, edge view; *c*. dorsal view; holotype, USC No. 586. Sample C. (p. 505)
3—*Höglundina supracretacea* (ten Dam). ×50. *a*, Ventral view; *b*, edge view; *c*, dorsal view; plesiotype, USC No. 575. Sample E. (p. 507)
4—*Valvulineria allomorphinoides* (Reuss). ×50. *a*, Dorsal view; *b*, edge view; *c*, ventral view; plesiotype, USC No. 610. Sample E. (p. 503)
5—*Valvulineria nonionoides* Bandy, n. sp. ×80. *a*, Dorsal view; *b*, edge view; *c*, ventral view; holotype, USC No. 611. Sample L. (p. 504)
6—*Anomalina henbesti* Plummer. ×35. *a*, Ventral view; *b*, edge view; *c*, dorsal view; plesiotype, USC No. 558. Sample E. (p. 506)
7—*Cibicidina californica* Bandy, n. sp. ×50. *a*, Dorsal view; *b*, edge view; *c*, ventral view; holotype, USC No. 563. Sample C. (p. 505)
8—*Planulina mascula* Bandy, n. sp. ×80. *a*, Dorsal view; *b*, edge view; *c*, ventral view; holotype, USC No. 600. Sample C. (p. 506)
9—*Planulina multipunctata* Bandy, n. sp. ×35. *a*, Dorsal view; *b*, edge view; *c*, ventral view; holotype, USC No. 601. Sample C. (p. 506)



Bandy, Upper Cretaceous Foraminifera



Bandy, Upper Cretaceous Foraminifera

and serve to separate this form from *V. umbilicata* (d'Orbigny) (1840, Soc. géol. France Mém., ser. 1, vol. 4).

Holotype.—USC No. 611, sample L.

Genus GYROIDINA d'Orbigny, 1826
GYROIDINA GLOBOSA (Hagenow) var. ORBICELLA Bandy, n. var.
Plate 74, figures 2a–c

1944?. *Gyroidina globosa*, CUSHMAN & GOUDKOFF (not Hagenow), Cushman Lab. Foram. Research Contr., vol. 20, p. 61, pl. 10, fig. 6; Upper Cretaceous, California.

1945?. *Gyroidina globosa*, GOUDKOFF (not Hagenow), Am. Assoc. Petroleum Geologists Bull., vol. 29, no. 7, p. 968 (table); Ingramian and Cheneyan, Upper Cretaceous and (?) lower Paleocene, California.

Test nearly circular in side view, rotaloid, dorsal side slightly convex, ventral side very convex with a small shallow umbilicus; periphery smooth or very slightly lobate; edge broadly rounded; chambers closely appressed, about six to eight, increasing very gradually in size as added; sutures radial, straight, narrowly limbate; wall smooth, calcareous, finely perforate; aperture a low slit with an upper lip, at base of the flattened septal face, extending from the edge of the test to the umbilicus; apertural face about 2 times as wide as high. Diameter of holotype, 0.23 mm.; thickness, 0.14 mm.

This variety differs from *Gyroidina globosa* (Hagenow) (1842, Neues Jahrb., p. 574) in that it is not as thick and the apertural face is comparatively much higher and not as broad as in Hagenow's specimens. The dorsal side is also somewhat convex in this variety.

Holotype.—USC No. 586, sample C.

Genus CIBICIDINA Bandy, 1949
CIBICIDINA CALIFORNICA Bandy, n. sp.
Plate 74, figures 7a–c

Test subcircular, planoconvex, dorsal side flat to slightly concave, ventral side convex, with small dorsal umbo, almost completely involute on both sides; edge subacute to sharply rounded; periphery smooth in the early portion becoming slightly lobulate in the later part; chambers closely appressed, eight to 11 in the last whorl, increasing evenly and gradually in size as added; sutures evenly curved, nearly radial, strongly limbate, with slightly developed re-entrants at the inner ends on the dorsal side; wall smooth, coarsely perforate on the ventral side, finely perforate on the dorsal side; aperture a low arched opening at the base of the last septal face near the pe-

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EXPLANATION OF PLATE 75

FIG. *1*—*Globotruncana arca* (Cushman). ×50. *a*, Dorsal view; *b*, edge view; *c*, ventral view; plesiotype, USC No. 581. Sample L. (p. 509)

2—*Globotruncana canaliculata* (Reuss). ×50. *a*, Dorsal view; *b*, edge view; *c*, ventral view; plesiotype, USC No. 582. Sample E. (p. 509)

3—*Globigerinella aspera* (Ehrenberg). ×120. *a*, Dorsal view; *b*, edge view; *c*, ventral view; plesiotype, USC No. 580. Sample L. (p. 508)

4—*Globotruncana rosetta* (Carsey). ×50. *a*, Dorsal view; *b*, edge view; *c*, ventral view; plesiotype, USC No. 583. Sample L. (p. 509)

5—*Bolivina incrassata* Reuss. ×35. *a*, Side view; *b*, apertural view; plesiotype, USC No. 560. Sample E. (p. 510)

6—*Loxostomum plaitum* (Carsey). ×50. *a*, Side view; *b*, apertural view; plesiotype, USC No. 590. Sample E. (p. 511)

7—*Virgulina tegulata* Reuss. ×50. *a*, Side view; *b*, apertural view; plesiotype, USC No. 613. Sample E. (p. 512)

8—*Gümbelina striata* (Ehrenberg). ×80. *a*, Apertural view; *b*, side view; plesiotype, USC No. 584. Sample L. (p. 510)

9—*Gümbelina striata* (Ehrenberg). ×80. *a*, Side view; *b*, apertural view; plesiotype, USC No. 585. Sample E. (p. 510)

10—*Bulimina aspera* Cushman & Parker. ×80. *a*, Side view; *b*, apertural view; plesiotype, USC No. 561. Sample L. (p. 511)

11—*Colomia californica* Bandy, n. sp. ×80. *a*, Side view; *b*, apertural view; holotype, USC No. 564. Sample E. (p. 512)

12—*Colomia californica* Bandy var. *mundula* Bandy, n. var. ×80. *a*, Side view; *b*, apertural view; holotype, USC No. 565. Sample E. (p. 512)

13—*Pseudouvigerina cretacea* Cushman. ×120. *a*, Side view; *b*, apertural view; plesiotype, USC No. 602. Sample B. (p. 513)

riphery and extending across the edge onto the dorsal side beneath the inner edge of the last chamber or two, with a slight upper lip. Diameter, 0.41 mm.; thickness, 0.16 mm.

Holotype.—USC No. 563, sample C.

Genus ANOMALINA d'Orbigny, 1826

ANOMALINA HENBESTI Plummer

Plate 74, figures 6a–c

1931. *Anomalina complanata*, CUSHMAN (not Reuss), Tennessee Geol. Survey Bull. 41, p. 60, pl. 11, figs. 7a–c; Upper Cretaceous, Tennessee.
1932. *Anomalina complanata*, SANDIDGE (not Reuss), Am. Midland Naturalist, vol. 13, p. 368, pl. 31, figs. 30, 31.
1936. *Anomalina henbesti* PLUMMER, Texas Univ. Bull. 3501, p. 290, pl. 5, figs. 7–10; Upper Cretaceous, Texas.
1938. *Anomalina henbesti*, COLE, Florida Dept. Cons. Geol. Bull. 16, p. 34, pl. 2, figs. 9, 10.
1938. *Anomalina semicomplanata*, CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 14, p. 68, pl. 12, fig. 1
1940. *Anomalina semicomplanata*, CUSHMAN, idem, Contr., vol. 16, p. 29, pl. 5, figs. 9a–c.
1941. *Anomalina semicomplanata*, CUSHMAN & HEDBERG, idem, Contr., vol. 17, p. 99, pl. 23, figs. 23a–c.
1944. *Anomalina henbesti*, CUSHMAN & GOUDKOFF, idem, Contr., vol. 20, p. 63, pl. 10, fig. 11; Upper Cretaceous, California.
1945. *Anomalina henbesti*, GOUDKOFF, Am. Assoc. Petroleum Geologists Bull., vol. 29, p. 968 (list), p. 987; E and F-1 substages, Upper Cretaceous, California.
1946. *Anomalina henbesti* CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 155, pl. 64, fig. 2; Upper Cretaceous (upper Taylor and lower Navarro), Gulf Coast.

Test almost equally biconvex, dorsal side with low umbonal boss, ventral side with a prominent umbonal boss; edge subacute or abruptly rounded; periphery smooth in the early part of the test, slightly lobulate in the later portion; chambers nine to 12 in the last whorl, enlarging gradually as added; sutures moderately curved; slightly sinuate toward the umbilicus, flush to slightly raised and limbate in the early part of the test, somewhat depressed in the later portion; wall conspicuously and coarsely perforate; aperture a low arched opening at the base of the last septal face extending dorsally along the base of the last two or three chambers. Diameter of plesiotype, 0.69 mm.; thickness, 0.24 mm.

A comparison shows that some of the California forms are slightly thicker than the topotypes, but examination of a large series of both forms indicates that they are rather variable in this respect. Gerontic specimens tend to develop a more lobulate periphery in the later portion.

Plesiotype.—USC No. 558, sample E.

Genus PLANULINA d'Orbigny, 1826

PLANULINA MASCULA Bandy, n. sp.

Plate 74, figures 8a–c

Test nearly bilaterally symmetrical, subcircular, thick, somewhat umbilicate dorsally, more of spire exposed ventrally than dorsally; back rather abruptly rounded with somewhat flattened flanks; periphery smooth in early portion of test, slightly lobulate in the later part; chambers nine to 12 in the last whorl, increasing very gradually in size as added; sutures slightly curved, flush in the early part of the test becoming slightly depressed in the later portion; wall conspicuously and coarsely perforate; aperture a very low arched opening at the base of the last septal face on the edge and extending along the base of the last few chambers dorsally. Diameter of holotype, 0.38 mm.; thickness, 0.15 mm.

This species is similar to *Planulina nacatochensis* Cushman (1938, Cushman Lab. Foram. Research Contr., vol. 14, p. 50, pl. 8, fig. 9) of the Gulf Coast, but it is much thicker, more inflated, less limbate and has curved sutures.

Holotype.—USC No. 600, sample C.

PLANULINA MULTIPUNCTATA Bandy, n. sp.

Plate 74, figures 9a–c

Test planoconvex to concavoconvex, ventral side moderately convex with a central raised, broadly rounded umbonal mass of secondary thickening which obscures much of the spire, dorsal side flattened to slightly concave with a central spiral umbonate mass concealing the early chambers; periphery smooth in the early portion, usually becoming slightly lobulate in the later portion of the last whorl; edge abruptly rounded to subangular; chambers eight to about ten in the final whorl of normal individuals, increasing regularly and fairly rapidly in size as added, closely appressed in the early portion, becoming slightly inflated in the

later part; sutures narrowly limbate, dorsally nearly radial and gently curved, ventrally more nearly tangential and more strongly curved, flush in the early part becoming slightly depressed in the later portion of the last whorl of larger specimens, dorsally the inner ends of the sutures in the early part of the test tend to be raised and are fused into a spiral umbonate mass at the center; wall calcareous, punctate, smooth; aperture a low crescentic opening extending from the periphery along the base of the last septal faces of the last few chambers on the dorsal side. Diameter of holotype, 0.70 mm.; thickness, 0.20 mm.

Cibicides subcarinatus Cushman & Deaderick (1944, Jour. Paleontology, vol. 18) is generally similar to this species, but the sutures on the dorsal side are strongly limbate and raised and those on the ventral side are not as curved. The diagnostic features of the new species are the conspicuous low, rounded, thickened area in the umbonal region of the strongly evolute ventral side, the lack of strongly limbate sutures, the spiral umbonate mass on the dorsal side and the abruptly rounded edge. The spiral character of the ventral umbonate mass is not always observable because it becomes fused into a rounded umbo in some specimens.

Holotype.—USC No. 601, sample C.

Family CERATOBULIMINIDAE Glaessner, 1945

Genus CERATOBULIMINA Toula, 1915

CERATOBULIMINA CRETACEA Cushman & Harris

Plate 73, figures 20a–c

1927. *Ceratobulimina cretacea* CUSHMAN & HARRIS, Cushman Lab. Foram. Research Contr., vol. 3, p. 173, pl. 29, figs. 1a–c; pl. 30, fig. 11; Upper Cretaceous, Navarro formation, Texas.

1946. *Ceratobulimina cretacea*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 143, pl. 59, figs. 6, 7; Upper Cretaceous, Navarro formation, Texas, Arkansas, Mississippi, Tennessee. (See this reference for complete synonymy to 1946.)

Test oval in side view, biconvex, with well developed ventral umbilicus; periphery only slightly lobulate; edge rounded; about seven chambers in the last whorl, increasing rather rapidly in size as added; sutures dorsally slightly curved and radial, ventral sutures nearly straight and radial, narrowly limbate on both sides; wall smooth, finely perforate; aperture a low triangular arch at the base of the last septal face near the umbilicus with incipient development of plate. Length, 0.35 mm.; breadth, 0.25 mm.; thickness, 0.18 mm.

Plesiotype.—USC No. 562, sample E.

Genus HÖGLUNDINA Brotzen, 1948

HÖGLUNDINA SUPRACRETACEA (ten Dam)

Plate 74, figures 3a–c

1925. *Epistomina caracolla*, FRANKE (not Roemer), Geol. Pal. Inst. Univ. Greifswald Abh., t. 6, p. 88, pl. 8, fig. 10.

1927. *Epistomina elegans*, CUSHMAN (not d'Orbigny), Jour. Paleontology, vol. 1, p. 166, pl. 26, figs. 3, 4; Alazan clay, Oligocene, Mexico.

1928. *Epistomina partschiana*, FRANKE (not d'Orbigny), Preuss. geol. Landesanstalt Abh., n. f., fasc. III, pp. 185–186, pl. 17, fig. 9.

1929. *Epistomina caracolla*, CUSHMAN & CHURCH (not Roemer), California Acad. Sci. Proc., 4th ser., vol. 18, p. 517, pl. 40, figs. 11–13; Upper Cretaceous, California.

1931. *Epistomina caracolla*, CUSHMAN (not Roemer), Tennessee Div. Geology Bull., 41, p. 55, pl. 10, fig. 1; Coon Creek section, lower Navarro, Upper Cretaceous, Tennessee.

1937. *Epistomina caracolla*, LOETTERLE (not Roemer), Nebraska Geol. Survey Bull., 2nd ser., no. 12, p. 62, pl. 11, fig. 2; lower Pierre shale (lower Senonian), Nebraska.

1941. *Epistomina* cf. *caracolla*, CUSHMAN & HEDBERG (not Roemer), Cushman Lab. Foram. Research Contr., vol. 17, p. 98, pl. 23, fig. 19; Colon formation, Upper Cretaceous, Colombia.

1943. *Epistomina caracolla*, CUSHMAN & TODD (not Roemer), idem, Contr., vol. 19, p. 69, pl. 12, fig. 5; Corsicana marl, Navarro formation, Upper Cretaceous, Texas.

1945. *Epistomina caracolla*, GOUDKOFF (not Roemer), Am. Assoc. Petroleum Geologists Bull., vol. 29, p. 968, (table 2); Upper Cretaceous, California.

1946. *Epistomina caracolla*, CUSHMAN (not Roemer), U. S. Geol. Survey Prof. Paper 206, pp. 142–143, pl. 59, fig. 2 (not fig. 1); Upper Cretaceous, Gulf Coastal Plain.

1948. *Epistomina supracretacea* TEN DAM, Revue de l'Institut Français du Petrole et Annales des Combustibles Liquides, vol. III, no. 6, juin 1948, p. 163, pl. 1, fig. 8; type from the Taylor formation, Upper Cretaceous, Texas.

Test nearly circular, dorsal side less convex than ventral; periphery smooth, only slightly lobulate; edge acute, with slight carina or keel; spire composed of about

two and one-half whorls, five to eight chambers in the last whorl; chambers increasing gradually in size as added; sutures strongly limbate and sometimes slightly raised, on the dorsal side oblique and slightly curved, on the ventral side nearly straight and radially fusing into the central umbo; wall finely perforate, smooth, usually mottled in appearance; aperture a narrow slit along the base of the last septal face on the ventral side near the periphery; accessory fissurine apertures on the ventral side parallel to and near the edge. Diameter of plesiotype, 0.48 mm.; thickness, 0.25 mm.

In ten Dam's type figure and frequently in other specimens dwarf chambers appear in the final whorl in this species. Except for Cushman's report of this species in the Oligocene of Mexico (see 1927 above), this form seems to be an excellent Senonian to Maestrichtian index.

Plesiotype.—USC No. 575, sample E.

Family ORBULINIDAE Schultze, 1854
Genus GLOBIGERINELLA Cushman, 1927
GLOBIGERINELLA ASPERA (Ehrenberg)
Plate 75, figures 3a–c

1854. *Rotalia aspera* EHRENBERG, Mikrogeologie, Leipzig, Taf. 27, fig. 57–58; Taf. 28, fig. 42, 42a; Cretaceous and Eocene, France, England, Russia and Egypt.
1854. *Phanerostomum asperum* EHRENBERG, idem., Taf. 30, fig. 26a, b; Cretaceous chalk of Rügen.
1891. *Rotalia aspera*, BEISSEL, Die Foraminiferen der Aachener Kreide, Preuss. geol. Landesanstalt. Abh., p. 73, pl. 14, figs. 1–6.
1892. *Globigerina aequilateralis*, CHAPMAN (not Brady), Geol. Soc. London Quart. Jour., vol. 48, p. 517, pl. 15, fig. 14; Cretaceous, Taplow chalk.
1896. *Globigerina aequilateralis*, CHAPMAN (not Brady), Roy. Micr. Soc. Jour., p. 589, pl. 13, fig. 7; Gault of Folkstone.
1899. *Globigerina aspera*, EGGER, Foraminiferen und Ostracoden aus den Kreidemergeln der oberbayrischen Alpen, K. bayr. Akad. Wiss. Abh., 2 Cl. Bd. 21, München, p. 170, pl. 21, figs. 18–20.
1902. *Globigerina aequilateralis*, EGGER (not Brady), idem, Abh., vol. 21, p. 169, pl. 21, figs. 9, 11; Cretaceous, Bavarian Alps.
1907. *Globigerina aspera*, EGGER, Microfauna der Kreideschichten d. westl. bayr. Waldes in d. Gebiet um Regensburg. 20 Bericht d. nath. Ver. Passau, p. 49, pl. 7.
1910. *Globigerina aequilateralis*, HERON-ALLEN and EARLAND (not Brady), Roy. Micr. Soc. Jour., p. 424, pl. 8, figs. 11–12; Cretaceous, Sussex.
1914. *Globigerina aspera*, FRANKE, Die Foraminiferen und Ostracoden des Emschers, besonders von Obereving und Derne nord von Dortmund: Deutsche geol. Gesell. Zeitschr, Bd. 66, p. 442.
1917. *Globigerina aequilateralis*, CHAPMAN (not Brady), West Australian Geol. Soc. Bull. 72, p. 44, pl. 12, fig. 125.
1928. *Globigerina aspera*, FRANKE, Die Foraminiferen der Aachener Kreide, Erg. u. Berichtig. zu Beissel-Holzapfel, Preuss. geol. Landesanstalt Jahrb. Bd. 48, p. 632.
1928. *Globigerina aspera*, FRANKE, Die Foraminiferen d. Oberen Kreide Nord- und Mitteldeutschlands, Preuss. geol. Landesanstalt Abh. N. F., Heft 111, p. 192, pl. 18, figs. 10a, b.
1929. *Globigerinella aspera*, CARMAN, Jour. Paleontology, vol. 3, p. 59, pl. 34, fig. 6; Niobrara, Wyoming.
1931. *Globigerinella aspera*, CUSHMAN, Tennessee Div. Geology Bull. 41, p. 59, pl. 11, figs. 5a, b; Selma chalk, Tennessee.
1931. *Globigerinella aspera*, CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 7, no. 2, p. 45, pl. 6, figs. 5a, b; Cretaceous chalk, Island of Antigua, equivalent to Craie Blanche of the Paris Basin.
1932. *Globigerinella voluta*, SANDIDGE (not White), Jour. Paleontology, vol. 6, p. 284, pl. 44, figs. 1, 2; Ripley formation, Alabama.
1936. *Globigerinella aspera*, BROTZEN, Sveriges geol. undersökning, series C, no. 396, Årsbok 30 (no. 3) p. 170, pl. 13, figs. 2a–c, text-fig. 62; lower Senonian, Sweden.
1937. *Globigerinella aspera*, LOETTERLE, Nebraska Geol. Survey Bull. 12, 2nd ser., p. 45, pl. 7, figs. 4a, b.
1938. *Globigerinella aspera*, COLE, Florida Geol. Survey Bull. 16, list, pl. 4, fig. 5.
1941. *Globigerinella aspera*, MARIE, Mus. nat. histoire nat. Mém., n.s., vol. 12, pt. 1, p. 235, pl. 36, figs. 336a, b; Campanian, *Belemnitella mucronata* chalk of the Paris Basin.
1946. *Globigerinella aspera*, SCHIJFSMA, Meded. van de Geologische Stichting, Ser. C-V, no. 7, p. 94, pl. 6, fig. 8; Campanian, Southern Limburg.

Test planispiral, biumbilicate, last whorl embracing the major portion of the previous whorl; periphery lobulate; chambers globular, loosely appressed, increasing rapidly in size as added, the last two making up more than half of the test; sutures straight radial, much depressed; wall coarsely perforate, hispid; aperture a low crescentic opening at the base of the last septal face extending from umbilicus to umbilicus with a well developed upper lip. Maximum diameter of plesiotype, 0.23 mm.; breadth, 0.18 mm.; thickness, 0.12 mm.

G. voluta White (1928, Jour. Paleontology,

vol. 2, p. 197) has a smoother wall, the chambers are more loosely appressed, and they increase in size more rapidly than in *G. aspera*. *G. pseudovoluta* Bandy (1949, Bull. Am. Paleontology, vol. 32, no. 131, p. 23, pl. 24, figs. 4a-b) is similar but differs in that the chambers are more closely appressed, the aperture is higher and larger, and the chambers increase in size more gradually.

Plesiotype.—USC No. 580, sample L.

Genus GLOBOTRUNCANA Cushman, 1927

GLOBOTRUNCANA ARCA (Cushman)

Plate 75, figures 1a–c

1926. *Pulvinulina arca* CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 2, pt. 1, p. 23, pl. 3, figs. 1a–c; Mendez shale, Upper Cretaceous, Mexico.
1927. *Globotruncana arca*, CUSHMAN, idem., Contr., vol. 3, p. 91, pl. 19, fig. 11.
1946. *Globotruncana arca* CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 150, pl. 62, fig. 4 (not fig. 5). Omit *Globigerina rosetta* Carsey from synonymy. (For complete synonymy to 1946 see this reference.)
1949. *Globotruncana arca*, CUSHMAN, idem, Prof. Paper 221-A, p. 10, pl. 4, figs. 22, 23; Upper Cretaceous, Arkansas.

Test subcircular, biconvex, dorsal side with a low regular spire, ventral side convex with a large umbilical vestibule; periphery lobate throughout, edge truncate, somewhat obliquely so, with a double keel; chambers about six or seven in the final whorl of ephebic specimens, increasing gradually in size as added, umbilical margin of each with a strong lip; dorsal sutures oblique and curved, all sutures limbate and beaded almost throughout; wall calcareous, finely perforate; sutures and keels raised, limbate and heavily beaded for the most part; aperture a high arched opening into the umbilical vestibule with well defined upper lip. Diameter of plesiotype, 0.65 mm.; thickness, 0.33 mm.

Plesiotype.—USC No. 581, sample L.

GLOBOTRUNCANA CANALICULATA (Reuss)

Plate 75, figures 2a–c

1854. *Rosalina canaliculata* REUSS, Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., vol. 7, pt. 1, p. 70, pl. 26, fig. 4; Senonian, Europe.
1946. *Globotruncana canaliculata* CUSHMAN U. S. Geol. Survey Prof. Paper 206, p. 149, pl. 61, figs. 17, 18; Upper Cretaceous (Navarro, Taylor and Austin), Texas, Alabama and Arkansas. (See this reference for complete synonymy to 1946.)
1949. *Globotruncana canaliculata*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 265, pl. 25, fig. 22; Upper Cretaceous, Maryland.
1949. *Globotruncana canaliculata*, CUSHMAN, U. S. Geol. Survey, Prof. Paper 221-A, p. 10, pl. 4, figs. 20, 21; Upper Cretaceous (Arkadelphia marl of Navarro age), Arkansas.

Test rotaloid, irregularly subcircular, sides nearly parallel, ventral side with large open umbilicus; periphery lobate throughout; edge truncate, flat to concave, bordered by prominent double raised and beaded keels; chambers about five to seven in the last whorl, increasing gradually in size as added, umbilical margin of each with a strong lip; dorsal sutures oblique and curved, ventral sutures nearly radial and somewhat curved, all sutures limbate and beaded nearly throughout; wall calcareous, finely perforate, generally hispid on the truncate edge; aperture a rather broad arched opening into the deep umbilicus, with strong upper lip. Diameter of plesiotype, 0.57 mm.; thickness, 0.22 mm.

Plesiotype.—USC No. 582, sample E.

GLOBOTRUNCANA ROSETTA (Carsey)

Plate 75, figures 4a–c

1926. *Globigerina rosetta* CARSEY, Texas Univ. Bull. 2612, p. 44, pl. 5, figs. 3a-c; Del Rio formation, Austin chalk, Taylor and Navarro formations, Texas.
1928. *Globotruncana rosetta*, WHITE, Jour. Paleontology, vol. 2, p. 286, pl. 39, fig. 1; San Felipe, Papagallos and Mendez, Upper Cretaceous, Mexico.
1946. *Globotruncana arca* CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 150, pl. 62, fig. 5 (not fig. 4); Annona chalk, Upper Cretaceous, Texas.

Test rotaloid, subcircular, ventral side much more convex than the dorsal side and with a large umbilicus; periphery lobate; edge acute with a single keel; chambers about six in the final whorl, umbilical margin of each with a strong lip which is somewhat beaded and raised; dorsal sutures limbate and beaded, oblique and curved; ventral sutures curved and radial, narrowly limbate and occasionally beaded; wall calcareous, finely perforate ornamentation consisting of limbate beaded dorsal sutures, beaded keel or carina, beaded umbilical ventral lips, and limbate ventral sutures;

aperture a high arched opening into the umbilical vestibule. Diameter of plesiotype, 0.60 mm.; thickness, 0.28 mm.

This species is quite distinct from *G. arca* (Cushman) with its more convex ventral side, single keel and somewhat less ornamented ventral surface.

Plesiotype.—USC No. 583, sample L.

Family HETEROHELICIDAE Cushman, 1927
Genus GÜMBELINA Egger, 1899
GÜMBELINA STRIATA (Ehrenberg)
Plate 75, figures 8a, b, 9a, b

1838. *Textilaria striata* EHRENBERG, K. preuss. Akad. Wiss. Abh., p. 135, pl. 4, figs. 1, 2, 3; Cretaceous, Europe.
1854. *Textilaria striata*, EHRENBERG, Mikrogeologie, pl. 27, fig. 3; pl. 28, fig. 6; pl. 29, fig. 21b; pl. 30, fig. 4; pl. 31, fig. 9, 10; pl. 32, fig. 4b.
1878. *Textilaria striata*, MARSSON, Mitt. naturw. Ver. Neuvorpommerns und Rügen, 10 Jahrg. Greifswald, p. 154.
1899. *Gümbelina striata*, EGGER, K. bayer. Akad. Wiss., Math.-naturh. Abt., Abh., Kl. 2, vol. 21, p. 33, pl. 14, figs. 5–7, 10, 11, 32, 38, 39.
1925. *Textularia globulosa f. striata*, FRANKE, geol. pal. Institut d. Univers. Greifswald IV Abh., p. 11.
1928. *Textularia globulosa f. striata*, FRANKE, Preuss. geol. Landesanstalt, Abh. Bd. 48, p. 134.
1931. *Gümbelina striata*, CUSHMAN, Tennessee Geol. Survey Bull. 41, p. 43, pl. 7, figs. 6, 7; Selma chalk, Tennessee.
1932. *Gümbelina striata*, CUSHMAN, Jour. Paleontology, vol. 6, p. 338; Annona chalk, Texas.
1934. *Textularia striata*, BROTZEN, Deutschen Palästina Verein Zeitschr., p. 56.
1936. *Gümbelina striata*, BROTZEN, Sveriges geol. undersökning, ser. C, no. 396, Arsbok 30 (no. 3), pp. 118–120, pl. 9, figs. 1a–b; text-figs. 1 (4) (5), 2, 39, 40; lower Senonian Sweden.
1937. *Gümbelina striata*, VOORWIJK, Royal Acad. Amsterdam Proc., vol. 40, p. 7, pl. 1, figs. 9, 10.
1938. *Gümbelina striata*, CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 14, p. 8, pl. 1, figs. 34–40.
1942. *Gümbelina striata*, CUSHMAN & DEADERICK, idem, Contr., vol. 18, p. 63, pl. 15, figs. 8–10; Brownstown marl, Arkansas.
1943. *Gümbelina striata*, CUSHMAN & TODD, idem, Contr., vol. 19, p. 64, pl. 11, fig. 11; Corsicana marl, Navarro formation, Texas.
1944. *Gümbelina striata*, CUSHMAN & TODD, idem, Contr., vol. 20, p. 10, pl. 2, fig. 19; Pecan Gap chalk, Taylor formation, Texas.
1944. *Gümbelina striata*, CUSHMAN & TODD, idem, Contr., vol. 20, p. 91, pl. 14, fig. 4; Mooreville chalk of the Selma group, Mississippi.
1946. *Gümbelina striata*, SCHIJFSMA, Macal. van de Geologische Stichting, ser. C-V, no. 7, p. 74, pl. 4, fig. 6; Campanian, southern Limburg.
1946. *Gümbelina striata*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 104, pl. 45, figs. 4, 5; Upper Cretaceous, Gulf Coastal region.
1949. *Gümbelina striata*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 258, pl. 24, fig. 3; Upper Cretaceous, Maryland.
1949. *Gümbelina striata*, CUSHMAN, U. S. Geol. Survey Prof. Paper 221-A, p. 7, pl. 3, fig. 24; Arkadelphia marl, Upper Cretaceous, Arkansas.

Test composed of about seven or eight pairs of chambers biserially arranged throughout, adult specimens not quite twice as long as broad, the greatest breadth near the apertural end; periphery lobate throughout; chambers inflated, subspherical; sutures depressed, within about 10° of being at right angles to the axis of the test; wall finely striate in the early part, usually becoming smooth in the later portion of the test; aperture a broad, low arched opening at the base of the last septal face with a definite upper lip. Length of plesiotype, 0.33 mm.; breadth, 0.21 mm.; thickness, 0.14 mm.

This species varies from an almost smooth type to one that is very strongly striate or costate. The former is easily mistaken for *G. globulosa* (Ehrenberg) for the striae in the early portion are very obscure. They may be made clearly visible, however, by moistening the test. Brotzen's work (1936) should be consulted for a thorough and complete analysis of this species.

Plesiotype.—USC No. 584, sample L; 585, sample E.

Genus BOLIVINA d'Orbigny, 1839
BOLIVINA INCRASSATA Reuss
Plate 75, figures 5a, b

1851. *Bolivina incrassata* REUSS, Haidinger's Naturwiss. Abh., vol. 4, p. 29, pl. 4, fig. 13; Upper Cretaceous, Poland.
1946. *Bolivina incrassata*, SCHIJFSMA, Meded. van de Geologische Stichting, ser. C-V, no. 7, p. 77, pl. 6, fig. 9, Campanian, southern Limburg.
1946. *Bolivina incrassata*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 127, pl. 53, figs. 8–11; Taylor and Navarro, Upper

Cretaceous, America; upper Senonian, Europe. (See this reference for a complete synonymy to 1946.)

1949. *Bolivina incrassata*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 262, pl. 25, fig. 3; Upper Cretaceous, Maryland. (This publication issued in January, 1949, although dated 1948.)

1949. *Bolivina incrassata*, CUSHMAN, U. S. Geol. Survey Prof. Paper 221-A, p. 8, pl. 4, fig. 6; Arkadelphia marl, Navarro, Upper Cretaceous, Arkansas.

Test stout, elongate ovate, about two and one-half times as long as broad, greatest breadth near the apertural end, commonly slightly twisted; periphery mostly smooth; chambers ten to about 14 in the adult test, increasing very gradually in size as added; sutures flush, oblique to axis of test, nearly straight, sometimes somewhat limbate; wall smooth, finely perforate; aperture elongate, oval, with slight lip. Length, 0.70 mm.; breadth, 0.29 mm.; thickness, 0.14 mm.

Plesiotype.—USC No. 560, sample E.

Genus LOXOSTOMUM Ehrenberg, 1854
LOXOSTOMUM PLAITUM (Carsey)
Plate 75, figure 6a, b

1926. *Bolivina plaitum* CARSEY, Texas Univ. Bull. 2612, p. 26, pl. 4, fig. 2; Upper Cretaceous, Taylor and Navarro, Texas.

1946. *Loxostoma plaitum*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 130, pl. 54, figs. 10–14, Upper Cretaceous (Austin, Taylor, and Navarro), southeastern United States. (See this reference for complete synonymy to 1946.)

1949. *Loxostomum plaitum*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 262, pl. 25, fig. 6; Upper Cretaceous, Maryland.

1949. *Loxostomum plaitum*, CUSHMAN, U. S. Geol. Survey Prof. 221-A, p. 9, pl. 4, fig. 9 (?); Upper Cretaceous, Arkansas.

Adult tests five or six times as long as broad, slightly tapering, greatest breadth near the apertural end, slightly twisted, compressed, edges rounded; periphery smooth to slightly lobulate; chambers in the early portion closely appressed and rather short, in the later part becoming somewhat inflated and much longer; sutures flush and straight in the early portion, curved and slightly depressed in the later part, oblique throughout; wall smooth, finely perforate; aperture irregularly oval, terminal or subterminal with a lip. Length of plesiotype, 0.58 mm.; breadth, 0.17 mm.; thickness, 0.10 mm.

Plesiotype.—USC No. 590, sample E.

Family BULIMINIDAE Jones, 1876
Genus BULIMINA d'Orbigny, 1826
BULIMINA ASPERA Cushman & Parker
Plate 75, figures 10a, b

1926. *Bulimina pupoides* CARSEY (not d'Orbigny), Univ. Texas Bull. 2612, p. 29, pl. 4, fig. 3; Upper Cretaceous, Texas.

1929. *Bulimina obtusa*, CUSHMAN & CHURCH (not d'Orbigny). California Acad. Sci. Proc., ser. 4, vol. 18, p. 513, pl. 39, figs. 17–19; Upper Cretaceous, California.

1929. *Bulimina quadrata*, W. BERRY & KELLEY (not Plummer), U. S. Nat. Mus. Proc., vol. 76, art. 19, p. 5, pl. 2, fig. 7.

1931. *Bulimina pupoides*, PLUMMER (not d'Orbigny), Univ. Texas Bull. 3101, p. 180, pl. 9, fig. 15; Upper Cretaceous, Texas.

1931. *Bulimina obtusa*, CUSHMAN (not d'Orbigny) Tennessee Geol. Survey Bull. 41, p. 47, pl. 7, figs. 17, 18; Upper Cretaceous, Tennessee.

1931. *Bulimina obtusa*, CUSHMAN (not d'Orbigny), Jour. Paleontology, vol. 5, p. 309, pl. 35, figs. 15a, b.

1932. *Bulimina pupoides*, SANDIDGE (not d'Orbigny), idem, vol. 6, p. 280, pl. 43, fig. 1.

1932. *Bulimina subornata*, SANDIDGE (not d'Orbigny), idem, vol. 6, p. 280, pl. 43, fig. 2.

1932. *Bulimina elongata*, SANDIDGE (not d'Orbigny), idem. vol. 6, p. 281, pl. 43, fig. 3.

1935. *Bulimina quadrata*, CUSHMAN & PARKER (not d'Orbigny) Cushman Lab. Foram. Research Contr., vol. 11, p. 100, pl. 15, figs. 12, 15, 16 (not figs. 13, 14).

1938. *Bulimina kickapooensis*, COLE (part), Florida Geol. Survey Bull. 16, p. 45.

1940. *Bulimina aspera* CUSHMAN & PARKER, Cushman Lab. Foram. Research Contr., vol. 16, p. 44, pl. 8, figs. 18, 19; Upper Cretaceous (upper Taylor), Texas.

1946. *Bulimina aspera*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 121, pl. 51, figs. 7, 10, 13, 15, 16; Upper Cretaceous, Gulf Coast.

1947. *Bulimina aspera*, CUSHMAN & PARKER, idem, Prof. Paper 210-D, p. 83, pl. 19, figs. 28–30; pl. 21, figs. 1, 2.

Test elongate, about twice as long as broad; chambers somewhat inflated in the last whorl; sutures slightly depressed in the early part, more so in the adult portion; wall smooth in later portion, finely perforate with a small apicule or spine at the apex and with a slightly roughened surface in the early part; aperture virguline with slight

lip, nearly terminal. Length of plesiotype, 0.40 mm.; diameter, 0.20 mm.

Very few specimens of this species were found. The presence of the apicule places them in that group which occurs in the lower Navarro and the upper Taylor of the Gulf Coast.

Plesiotype.—USC No. 561, sample L.

Genus VIRGULINA d'Orbigny, 1826

VIRGULINA TEGULATA Reuss

Plate 75, figures 7a, b

1845. (1846). *Virgulina tegulata* REUSS, Verstein. böhm. Kreideformation, pt. 1, p. 40, pl. 13, fig. 81; Upper Cretaceous, Europe.
1851. *Bolivina tegulata*, REUSS, Haidinger's Nat. Abh., vol. 4, p. 29, pl. 4, fig. 12.
1875. *Virgulina tegulata*, REUSS, in Geinitz: Das Elbtalgebirge in Sachsen, Palaeontographica, Bd. 20, Teil 2, Abt. 4, p. 109, pl. 23, fig. 6.
1877 (1878). *Virgulina tegulata*, MARSSON, Die Foraminiferen der weissen Schreibkreide von Rügen, Mitt. naturw. Ver. Neuvorpommerns und Rügen, Jahrg. 10, Greifswald, p. 155.
1891. *Virgulina tegulata*, BEISSEL, Die Foraminiferen der Aachener Kreide, Preuss. geol. Landesanstalt Abh. p. 65, pl. 13, figs. 1–7.
1899. *Bolivina tegulata*, EGGER, K. bayer. Akad. Wiss. München Abh., Cl. II, vol. 21, pt. 1, p. 45, pl. 16, figs. 10, 11.
1925. *Bolivina tegulata*, FRANKE, Geol. Pal. Inst. Greifswald Abh., vol. 6, p. 21, pl. 2, fig. 7.
1927. *Bolivina tegulata*, CUSHMAN, Cushman Lab. Foram. Research Contr., vol. 2, pt. 4, p. 86, pl. 12, fig. 2.
1928. *Bolivina tegulata*, FRANKE, Preuss. geol. Landesanstalt Abh., vol. 111, p. 153, pl. 14, fig. 5.
1931. *Loxostomum tegulatum*, CUSHMAN, Tennessee Geol. Survey Bull. 41, p. 51, pl. 8, fig. 8; Upper Cretaceous, Tennessee.
1934. *Bolivina tegulata*, MORROW, Jour. Paleontology, vol. 8, p. 196, pl. 30, fig. 21a-b.
1936. *Bolivina tegulata*, BROTZEN, Sveriges geol. undersökning, Arsbok 30, no. 3, pl. 131, pl. 9, fig. 7; lower Senonian, Sweden.
1937. *Virgulina tegulata*, CUSHMAN, Cushman Lab. Foram. Research Special Pub. 9, p. 4, pl. 1, figs. 8–12.
1944. *Virgulina tegulata*, CUSHMAN, idem, Contr., vol. 20, p. 12, pl. 2, fig. 26.
1944. *Virgulina tegulata*, CUSHMAN, idem, Contr., p. 93, pl. 14, fig. 14.
1944. *Virgulina tegulata*, CUSHMAN & DEADERICK, Jour. Paleontology, vol. 18, p. 338, pl. 53, fig. 11.
1946. *Virgulina tegulata*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206; p. 126, pl. 53, figs. 1–4; Upper Cretaceous (Eagle Ford-lower Navarro), southeastern United States; Turonian, Europe.
1949. *Virgulina tegulata*, CUSHMAN, Maryland Dept. Geology, Mines and Water Resources Bull. 2, p. 261, pl. 25, fig. 2; Upper Cretaceous, Maryland. (Publication dated 1948, actually distributed in January, 1949.)

Test elongate, twisted, about three to five times as long as broad, ovate in end view; early chambers triserial and spiral, later chambers biserial; chambers slightly inflated, mostly longer than broad; sutures oblique, slightly depressed; wall smooth, finely perforate; aperture elongate, narrow, extending from the base to the apex of the last septal face, with a narrow lip. Length of plesiotype, 0.67 mm.; breadth, 0.20 mm.; thickness, 0.13 mm.

Plesiotype.—USC No. 613, sample E.

Genus COLOMIA Cushman & Bermudez, 1948

COLOMIA CALIFORNICA Bandy, n. sp.

Plate 75, figures 11a, b

Test in the early portion conical, adult portion nearly cylindrical, initial end apiculate or acute, circular in transverse section; chambers of the early portion irregularly triserial, later part uniserial; sutures flush or slightly depressed, transverse in the uniserial portion, sometimes slightly oblique; wall calcareous, finely perforate, smooth; aperture terminal, a broad, low, U-shaped opening with a vertical column extending to the previous aperture. Length, 0.37 mm.; diameter, 0.18 mm.

This species differs from *Colomia cretacea* Cushman & Bermudez (1948, Cushman Lab. Foram. Research Contr., vol. 24, p. 12) in lacking the raised sutures and hispid ornamentation of that species. Comparison with a topotype of *C. cretacea* shows also that the chambers of the California form are apparently much longer.

Holotype.—USC No. 564, sample E.

COLOMIA CALIFORNICA Bandy

var. MUNDULA Bandy, n. var.

Plate 75, figures 12a, b

Test conical, tapering from the broad flattened apertural end to the acute initial end, circular in transverse section; chambers of the early portion irregularly triserial, later part uniserial; sutures nearly flush or slightly depressed; wall calcareous, finely perforate, smooth; aperture terminal, a broad, low, U-shaped opening with a vertical

column extending to the previous aperture. Length of holotype, 0.31 mm.; diameter, 0.24 mm.

This variety differs from the typical form in being larger and conical throughout rather than partly conical and partly cylindrical. The maximum observed length of this variety is about 0.45 mm.

Holotype.—USC No. 565, sample E.

Family UVIGERINIDAE Galloway & Wissler, 1927

Genus PSEUDOUVIGERINA Cushman, 1927

PSEUDOUVIGERINA CRETACEA Cushman

Plate 75, figures 13a, b

1931. *Pseudouvigerina cretacea* CUSHMAN, Tennessee Geol. Survey Bull. 41, p. 46, pl. 7, figs. 14a–c; Upper Cretaceous, Tennessee.

1946. *Pseudouvigerina cretacea*, CUSHMAN, U. S. Geol. Survey Prof. Paper 206, p. 117, pl. 49, figs. 17–20; Upper Cretaceous (Austin, Taylor and Navarro), Gulf Coastal area. (See this reference for complete synonymy.)

Test elongate, fusiform, greatest breadth above the middle, rounded trihedral in cross section; chambers somewhat inflated, triserial throughout; sutures depressed; wall smooth, conspicuously perforate; aperture terminal with a short neck and slight lip. Length, 0.22 mm.; breadth, 0.13 mm.

The figured specimen is relatively shorter than many of those previously reported but the specimens studied vary from elongate fusiform to short and stout.

Plesiotype.—USC No. 602, sample B.

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JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 4, PP. 514–519, PL. 76, JULY 1951

UPPER PALEOZOIC MICROFOSSILS FROM STEVENS COUNTY, WASHINGTON[1]

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ABSTRACT—The rocks of Stevens County in northeastern Washington have yielded fossils indicating that most of the Paleozoic systems are represented, but well preserved specimens have been collected from relatively few localities. These fossils include sponges, trilobites, graptolites, ostracodes, brachiopods, bryozoans and fusulinids. The faunas now known show affinities to those of the Rocky Mountain Paleozoic sections and to those of the Southwest and Mid-continent regions. Several species of ostracodes and one fusulinid are described. Methods of extracting microfossils from limestone are summarized.

INTRODUCTION

TWENTY-FIVE years ago the Paleozoic strata of northeastern Washington were generally considered to be an unfossiliferous complex of sediments which had been metamorphosed to varying degrees, and unraveling of their sequence was either considered to be virtually impossible or was attempted by the same methods as those applied to Pre-Cambrian strata. Subsequent discovery of fossiliferous zones did little to change this general attitude. Most of the fossils that were found remained in the possession of their collectors, and if they were reported in the literature they were not described in such a way as to promote stratigraphic research. It is hoped that this preliminary report will promote the further publication of descriptions and identifications of collections from Stevens County. Sufficiently detailed location and stratigraphic data probably exist to make many of them usable.

Table 1 summarizes the paleontologic discoveries of the past 25 years. The writers are indebted to John P. Thomson of Colville, Washington; and to Dr. W. A. G. Bennett of the Washington Division of Mines and Geology, for information concerning discoveries which have not been reported in the literature.

STRATIGRAPHY

Two systems, Mississippian and Permian, are identified in Stevens County by the faunas described in this paper. The presence of two others, Cambrian and Ordovician, has been established previously. Eastward in Pend Oreille County, Devonian limestone has been recognized (Park and Cannon, 1943, pp. 22–23). Westward in Okanogan County parts of the "Anarchist series" have been tentatively identified as Carboniferous, possibly Permian (Waters and Krauskopf, 1941, p. 1364). Permian fusulinids have been reported from Snohomish County still farther west (Anderson, 1941). No good fossil evidence for the existence of Pennsylvanian or Silurian strata in northern Washington is known to the writers.

Cambrian.—Campbell (1947) described the westward extensions into the Northport area of Cambrian formations named by Park and Cannon (1943), and proposed correlations by which the Metaline quadrangle formation names supplant those used earlier in northern Stevens County (Weaver, 1920). Campbell also summarized the stratigraphic positions, localities of, and references to, fossil collections from Lower and Middle Cambrian strata in northern Stevens County and northern Pend Oreille County. Until Okulitch (1950) identified the trilobites at Addy as being Early Cambrian, the age of these fossils was not known and they were omitted in Campbell's summary. Okulitch has also identified certain archaeocyathids from the Colville and Metaline areas as *Ajacicyathus* and *Coscinocyathus purcellensis* of early Cambrian age similar to members of the fauna of the Donald formation in the Purcell Mountains (Okulitch, oral communication).

Ordovician.—Graptolites have been found

[1] This investigation was supported in part by the State College of Washington Research Fund.

TABLE 1.—PALEOZOIC FOSSIL COLLECTIONS FROM STEVENS COUNTY, WASHINGTON

Age	Fossils	Stratigraphic occurrence	Location	Collectors or Reference
Mid-Permian	Bryozoans Brachiopods Corals Gastropods	Limestone and overlying argillite	N. E. Kettle Falls SE ¼ 10, 36 N., 38 E.	John P. Thomson; H. W. Little, Canada Geol. Survey; V. J. Okulitch, Univ. British Columbia; K. P. McLaughlin
	Parafusulina dunbari	Limestone equivalent (?) to that of above collection	NW of old Mission SW ¼, 10, 36 N., 38 E.	
Mississippian (Chester)	Ostracodes including *Graphiodactylus tenuis* *Jonesina craterigera* *Cavellina* aff. *C. coryelli* *Paraparchites nicklesi* *Neokloedenella* sp. *Bythocypris* aff. *B. amsdenensis* Brachiopods, pelmatozoans, corals	Fetid limestone in Chewelah argillite	SE of valley SE ¼ 24, 31 N., 40 E.	John P. Thomson; K. P. McLaughlin
Mississippian?	Brachiopods, corals pelmatozoans	Limestone	N. Springdale, sections 23, 26, 27, 30 N., 40 E.	John P. Thomson; K. P. McLaughlin
	Coral	Limestone in Colville quartzite	N. Colville SW ¼ 22, 36 N., 39 E.	John P. Thomson
Mid-Ordovician	Graptolites including *Climacograptus bicornis*	Argillite	4 miles N. Colville on Clugstone Creek	W. A. G. Bennett (Ruedemann, 1947, p. 111–112)
	Graptolites including *Dicellograptus* *Climacograptus bicornis*	Argillite	E. of Rice, SW ¼ 24, 34 N., 37 E.	John P. Thomson; V. J. Okulitch; K. P. McLaughlin
Early and Middle Cambrian	Trilobites, brachiopods, pelecypods		Four localities in Stevens County	R. H. B. Jones; V. Barnes; W. A. G. Bennett; C. C. Branson (Campbell, 1947, p. 601)
	Trilobites	Argillaceous beds in quartzite	Sec. 14, 33 N., 38 E.	R. H. B. Jones; V. Barnes
Early Cambrian	Trilobites, brachiopods	Addy quartzite	Addy—SW ¼, 13, 33 N., 39 E.	Bennett, 1944, p. 31; Okulitch, 1950

in the Ledbetter slate in the Metaline quadrangle and in argillite at two places in Stevens County, one along Clugston Creek north of Colville, the other 4 miles east and south of Rice. The Clugston Creek specimens were listed by Ruedemann (1947, pp. 111–112) as including both early and Middle Ordovician species. Of those from Rice identified by the writers, *Climacograptus bicornis* and *Dicellograptus* sp. are definitely Mid-Ordovician.

Devonian.—To date the only evidence of Devonian strata in northeastern Washington is a fauna reported from the Metaline quadrangle (Park and Cannon, 1943, pp. 22–23). The species were identified by Bridge and others as being late Devonian or early Mississippian. Girty recognized no typically Carboniferous species in the fauna and concluded that in their absence it should be considered Devonian.

Mississippian.—The ostracodes from the Springdale-Chewlah limestone trend, described in this paper, are the only Mississippian fossils reported to date. The species are all known from Upper Mississippian (Chester) strata of the northern Rocky Mountains and Mid-continent regions. Brachiopods are the most abundant associated fossils, but enough have not been collected for identification and description.

Permian.—The recognition of Permian strata in Stevens County is based entirely on the single mid-Permian fusulinid species described herein. Brachiopods, bryozoans and corals in what appears to be the same limestone unit are very poorly preserved.

SYSTEMATIC PALEONTOLOGY

Class CRUSTACEA

Subclass OSTRACODA Latreille

All ostracodes described and figured in this report were collected from a fetid, dark colored, coarsely crystalline limestone on the SE ¼ of section 24, T. 31 N., R. 40 E., Stevens County, Washington. Associated

with them, and also occurring in more finely crystalline, light colored limestone, are abundant pelmatozoan remains, brachiopods and corals, all as yet unidentified. This particular fossiliferous locality occurs in the area mapped by Weaver (1920, pl. 1) as Chewelah argillite.

Family BAIRDIIDAE Sars, 1887
Genus BYTHOCYPRIS Brady, 1880
BYTHOCYPRIS aff. AMSDENENSIS Morey
Plate 76, figure 14

Bythocypris amsdenensis MOREY, 1935, Jour. Paleontology, vol. 9, p. 481, pl. 54, figs. 2, 3, Amsden formation (Sacajawea), Wyoming; COOPER, 1941, Illinois Geol. Survey Rept. Inv. 77, p. 28, pl. 2, figs. 35, 36, Clore formation, Illinois, and Fayetteville shale, Arkansas.

This species is rare in the Stevens County collection. It appears to be very similar to the Amsden (Sacajawea) form except possibly for the length-height ratio. Morey figured a right valve view which indicates very little, if any, ventral overlap by the left valve; therefore his dimensions are essentially those of the right valve. The ventral overlap of the Stevens County form is somewhat more pronounced, which decreases the apparent length-height ratio.

Dimensions (mm.).—Length, 0.62; height, 0.40; width, 0.30.

Family CYTHERELLIDAE Sars
Genus CAVELLINA Coryell
CAVELLINA aff. CORYELLI Croneis & Gale
Plate 76, figures 7, 8

Cavellina coryelli CRONEIS & GALE, 1938, Denison Univ. Sci. Lab. Bull., vol. 33, pp. 251–295, pls. 5, 6, upper Chester, Clore formation; COOPER, 1941, Illinois Geol. Survey Rept. Inv. 77, p. 76, pl. 5, figs. 24, 25.

Carapace bluntly ovate, dorsal and ventral margins very broadly convex, anterodorsal slope rather pronounced, posterior margin bluntly rounded with obscure postero-ventral truncation; right valve overlaps left with maximum in mid-part of ventral margin.

In dorsal view the anterior portion of the hinge line is offset sharply to the right; carapace strongly wedge-shaped.

Most of the Stevens County specimens are much more tumid posteriorly than the specimen figured by Cooper, but they are so nearly identical in other respects as to suggest that they are females of the species.

Dimensions (mm.) of three specimens.—Length, 0.90, 0.85, 0.60; height, 0.55, 0.52, 0.42; width, 0.45, 0.38, 0.30, respectively.

Family GRAPHIODACTYLIDAE Kellett, 1936
Genus GRAPHIODACTYLUS Roth, 1929
GRAPHIODACTYLUS TENUIS Cooper
Plate 76, figures 15, 16

Graphiodactylus tenuis COOPER, 1941, Illinois Geol. Surv. Rept. Inv. 77, p. 45, pl. 9, figs. 7, 8, Fayetteville shale, Arkansas.

This species is very abundant in the Stevens County collection. In outline, form ratio and surface ornamentation it is identical with Cooper's specimens, although the anterior and posterior spines are only doubtfully present and the position of the muscle scar is not definitely marked. Whether or not *G. tenuis* is actually specially different from *G. arkansana* (Girty), from the Fayetteville shale of Arkansas, the Stevens County forms are so closely similar to both that their Chesterian age can hardly be doubted.

Dimensions (mm.) of three specimens.—

EXPLANATION OF PLATE 76

FIGS. *1–6*—*Parafusulina dunbari* Needham. *1*, Nearly longitudinal section of microspheric individual, showing tunnel, ×11; *2*, nearly longitudinal section of megalospheric individual, ×11; *3*, tangential section showing cuniculi, ×11; *5*, equatorial section of immature megalospheric individual with irregular proloculum, ×11; *6*, equatorial section of mature individual, ×11; *4*, enlargement of part of equatorial section of figure *6*, ×55. (p. 518)

7, 8—*Cavellina* aff. *coryelli* Croneis & Gale. Left-lateral and dorsal views of female; ×18. (p. 516)

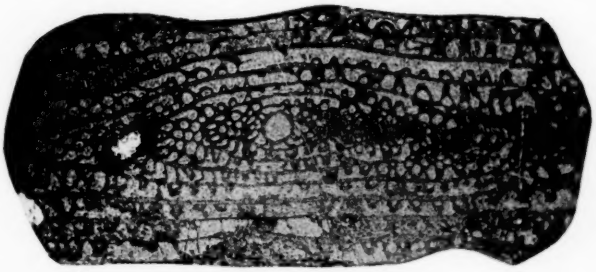
9, 10—*Paraparchites nicklesi* (Ulrich). Left valve, interior and exterior; ×17. (p. 517)

11—*Neokloedenella?* Croneis & Funkhouser. Dorsal view; ×17. (p. 517)

12, 13—*Jonesina craterigera* (Brady). Left-lateral and dorsal views of female; ×18. (p. 517)

14—*Bythocypris* aff. *amsdenensis* Morey. Right-lateral view; ×18. (p. 516)

15, 16—*Graphiodactylus tenuis* Cooper. Dorsal and left-lateral views; ×17. (p. 516)



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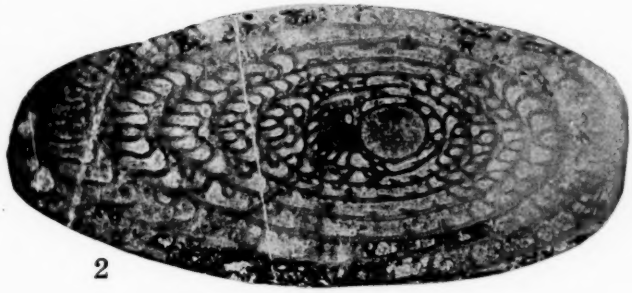

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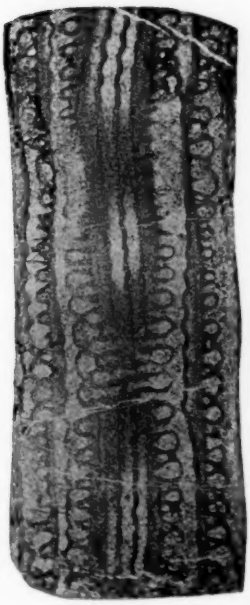

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McLaughlin and Simons, Upper Paleozoic microfossils

Length, 0.95, 1.00, 1.00; height, 0.55, 0.55, 0.55; width, 0.45, 0.45, 0.44, respectively.

Family KLOEDENELLIDAE Ulrich & Bassler
Genus JONESINA Ulrich & Bassler, 1908
JONESINA CRATERIGERA (Brady)
Plate 76, figures 12, 13

Beyrichia craterigera (BRADY) JONES, 1886, Geol. Mag., n. s., vol. 3, p. 439, pl. 12, figs. 7a, b, Carboniferous, Great Britain.
Jonesina craterigera ULRICH & BASSLER, 1908, U. S. Nat. Mus. Proc., vol. 35, p. 324, pl. 44, figs. 13, 14; HARLTON, 1927, Jour. Paleontology, vol. 1, p. 203, pl. 32, figs. 5a, b, lower Glenn formation, Arkansas; COOPER, 1941, Illinois Geol. Survey Rept. Inv., 77, p. 56, pl. 11, figs. 36–39, Golconda and Glen Dean formations, Illinois.

This species is very abundant in the Stevens County collection. It is identical in all respects with the female specimen figured by Cooper from the Golconda formation of Illinois. This species is also very similar to *Geffenina reticulata* Scott, from the Otter formation of Montana, differing primarily in the absence of the ventral and posterior ridge which characterizes *Geffenina*.

Dimensions (mm.) of two specimens.—Length, 0.88, 0.97; height, 0.50, 0.53; width, 0.48, 0.50, respectively.

Genus NEOKLOEDENELLA Croneis & Funkhouser, 1938
NEOKLOEDENELLA?
Plate 76, figure 11

Carapace very tumid, elongate ovoid in outline; dorsal margin and hinge line broadly convex, maximum curvature posterior; ventral margin nearly straight; anteriorly low and nearly evenly rounded; posteriorly blunt with prominent anteriorly directed ventro-posterior slope. Very broadly wedge-shaped in dorsal view.

A posteriorly directed unobtrusive projection arises on each valve from the postero-ventral extremity; a low rounded swelling extends dorsally from each of these but does not reach the dorsal margin.

This species is very rare in the Stevens County collection.

Dimensions (mm.).—Length, 1.17; width, 0.57; height, 0.57.

Family LEPERDITELLIDAE Ulrich & Bassler, 1923
Genus PARAPARCHITES Ulrich & Bassler, 1923
PARAPARCHITES NICKLESI (Ulrich)
Plate 76, figures 9, 10

Leperditia nicklesi ULRICH, 1891, Cincinnati Soc. Nat. Hist. Jour., vol. 13, p. 200, pl. 18, figs. 1a–e, Chester series.
Paraparchites nicklesi MOREY, 1935, Jour. Paleontology, vol. 9, p. 475, pl. 54, fig. 8, Amsden (Sacajawea) formation, Wyoming; COOPER, 1941, Illinois Geol. Survey Rept. Inv. 77, p. 62, pl. 14, figs. 5–7, Chester series, Illinois (includes more extensive synonymy).

This abundant species in the Stevens County collection has length-height ratios closely according with the dimensions given by Morey and by Cooper. Most of the specimens, however, are more tumid than those described from other localities. The anterior margin, which is nearly normal to the dorsal margin, is slightly longer in its straight portion than in the Amsden form.

Dimensions (mm.) of two specimens.—Length, 0.73, 0.75; height, 0.40, 0.42; width, 0.55, 0.55, respectively.

Family FUSULINIDAE Möller, 1878

The specimens described and illustrated in this report were collected from an impure, silicious limestone in the NE ¼ of sec. 16 and the SW ¼ of sec. 10, T. 36 N., R. 38 E. A few silicified corals and productids are associated with them. This limestone appears to be part of a generally calcareous zone extending several miles to the northeast and southwest. It is interbedded with rocks which Weaver (1920, pl. 1) mapped as Mission argillite, which to the southwest, near Kettle Falls, have yielded molds of gastropods and which also contain locally abundant plant fragments. Petrographic study has shown the Mission argillite in this area to consist of at least two interbedded lithologic types:

(1) Composed of over 50 per cent kaolinized feldspar, apparently plagioclase, and nearly 10 per cent subangular quartz grains, all in an opaque reddish matrix.

(2) Composed of nearly 90 per cent very finely crystalline silicious material, with small quantities of subangular quartz grains,

crystals of calcite and/or dolomite and some hematite.

Subfamily SCHWAGERININAE Dunbar & Henbest, 1930
Genus PARAFUSULINA Dunbar & Skinner, 1931
PARAFUSULINA DUNBARI Needham
Plate 76, figures 1–6

Parafusulina dunbari NEEDHAM, 1937, New Mexico Bur. Mines and Min. Res. Bull. 14, p. 56, pl. 11, figs. 5–11, pl. 12, figs. 1, 2, Middle Permian (Word), Delaware Mountain sandstone and Dog Canyon limestone.

The test is large, elongate; the poles are pointed in the first four volutions but bluntly rounded in later whorls. The axis of coiling is essentially straight; the slope of the shoulders is slightly convex. Specimens as much as 22.5 mm. long and 4.5 mm. wide are abundant, and one specimen over 40 mm. long has been found. For the collection as a whole lengths average between 11.2 mm. and 13.2 mm., widths between 3.6 mm. and 4.0 mm.

Table 2 and the plate illustrations show the similarity of the Stevens County forms with the type specimens of *P. dunbari*. The only apparent discrepancy is the large proloculum diameters of some of the Washington specimens. These appear to be megalospheric (see pl. 76, fig. 5).

These fusulinids represent a single species known primarily from the southern part of the Rocky Mountains. Those described by Anderson (1941) from the Granite Falls limestone in Snohomish County, Washington, belong to genera and species also known in the Cache Creek limestones of British Columbia and have Asiatic affinities. Perhaps the Paleozoic strata of northern Washington accumulated in two distinct troughs.

TABLE 2.—MEASUREMENTS OF EIGHT SPECIMENS OF *Parafusulina dunbari* NEEDHAM FROM STEVENS COUNTY, WASHINGTON

Specimen Number	Height of Volutions (H) and Wall Thickness (T) (microns)																Proloculum (microns)		Half length (millimeters)	Form Ratio	Radius Vector
	Volutions																				
	1		2		3		4		5		6		7		8						
	H	T	H	T	H	T	H	T	H	T	H	T	H	T	H	T	Diameter	Wall Thickness			
1	66		93		105	46	128	46	163	70	163	70	211	82	269	70	538	49			
2		35	93	35	106	46	117	46	163	58	163	58					400	47	6.6	3.5:1	1.8
3				35		41	128	58	163	58	176	70	246	82	246						2.3
4	58		93	35	105	46		58		58							500	46	11.7	5.0:1	2.7
5		35		35		46		58		70							858	46			
10																	440	46	5.6	4.2:1	1.3
11																	825	49			
12																			9.9	5.2:1	1.9

Various concentrations of hydrochloric acid were tried, the most satisfactory of which produced the specimens described. Only fractions of the crushed rock remaining on the 20 and 40 mesh screens were used. The sample was first digested for 12 hours in a 20 per cent solution, then well washed and returned to a 10 per cent solution for an additional 12 hours. After a second washing the remaining sample was boiled gently for

RECOVERY OF OSTRACODES FROM LIMESTONE

Acetic, oxalic and hydrochloric acids were used in attempts to free ostracodes from the fetid limestone of the Springdale-Chewelah zone. In each, a 50 cc. unit of crushed sample was digested in 500 ml. of acid.

A 1 to 9 dilution of glacial acetic acid, which has satisfactorily freed microfossils from many other limestones, failed to release clean, identifiable specimens. More concentrated solutions were not tried.

Digestion of crushed samples for 24 hours in a saturated solution of oxalic acid freed the specimens, but the calcium oxalate precipitate on their surfaces was so thick that many details were obscured.

1 to 2 hours in a 10 per cent solution, then dried. The fossil residues were relatively free of fine silt and clay and the ostracodes were reasonably clean.

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JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 4, PP. 520–524, 3 TEXT FIGS., JULY 1951

SIZE RELATIONS IN THE LIMB BONES OF *BUETTNERIA PERFECTA*

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ABSTRACT—Measurements have been made on eight series of limb and girdle bones. The regression of distal width on length is shown to be linear. Correlation between the two variates is found to be significant. The regression of proximal width on length is not linear in every case. Successive sizes of the same element may exhibit change in one respect, constancy in another. Certain characteristic changes are observed in larger and presumably older bones. One implication of the use of length as a time base is discussed. Observed changes in proportion are taken to indicate an aquatic adaptation.

INTRODUCTION

THE fossil amphibian material on which this study is based was collected in 1938 by Mr. R. V. Witter and Dr. T. E. White from an Upper Triassic (Dockum) deposit, the so-called Gunter bone bed, 16 miles south of Lamy, New Mexico. The author is indebted to the collectors for the careful manner in which they wrapped thousands of fragments. Acknowledgment is likewise due to Dr. A. S. Romer, Director of the Museum of Comparative Zoology, for permission to examine these remains. And the author wishes to thank officials of the United States National Museum for assisting his brief inspection of their own important collection from the same site.

The material itself consists of skull and skeletal parts belonging to the stereospondyl *Buettneria perfecta*. For the most part preservation is good; there is little clear evidence of either crushing or shear. All limb bones are disarticulated; and the present study is limited to skeletal parts, skulls being no longer accessible.

The general morphology of the genus has been discussed elsewhere (Branson, 1905; Branson and Mehl, 1929; Case, 1932; Sawin, 1945). In the present case, the fact that an unusually large number of bones was available for measurement suggested that careful comparison of their dimensions might yield further information concerning (1) the relative size and shape of individual structures and (2) the successive stages of their growth. It will be recognized that figures thus secured constitute type D data, as defined by Kavanagh and Richards (1942). Inferences respecting growth are accordingly limited.

MEASUREMENTS

Characters for measurement were chosen with a view to obtaining the largest possible number of zoologically significant values. Such data serve a useful purpose only when they relate the bone examined to the field of force in which it functioned and grew. Figure 1 shows the dimensions taken and the designations applied not only to the humerus but to the remaining elements as well. For every bone, values of abscissae derive from length. All measurements were recorded in millimeters. They were made with indicating calipers or with dividers and an ordinary centimeter scale. In the case of fractional values, the lower reading was adopted. Numerical data on length of the bones are presented in table 1.

CORRELATION

Figure 2 is a scatter diagram in which distal width (Y) of the humerus is plotted against its length (X). The points are seen to extend bandwise from lower left to upper right. Similar plots may be made for the remaining elements, and in every case it appears that distal width undergoes an approximately regular increase with elongation of the bone. A fair degree of scatter is expected with zoological data, especially when the array is determined by successive stages in the development of different individuals. The effect is here amplified by the variability that doubtless characterized these cold-blooded forms while living. On

TABLE 1.—PARAMETERS OF LENGTH DISTRIBUTION

Element	N	Range	Mean	Stand. dev.
humerus	23	72–139	101.4±3.8	18.1±2.7
radius	12	33– 75	54.5±3.1	10.7±2.2
ulna	13	41– 75	57.9±2.7	10.0±1.9
femur	20	68–165	113.0±5.7	25.7±4.0
tibia	11	38– 65	49.4±2.5	8.3±1.8
fibula	7	44– 75	57.8±3.7	9.8±2.6

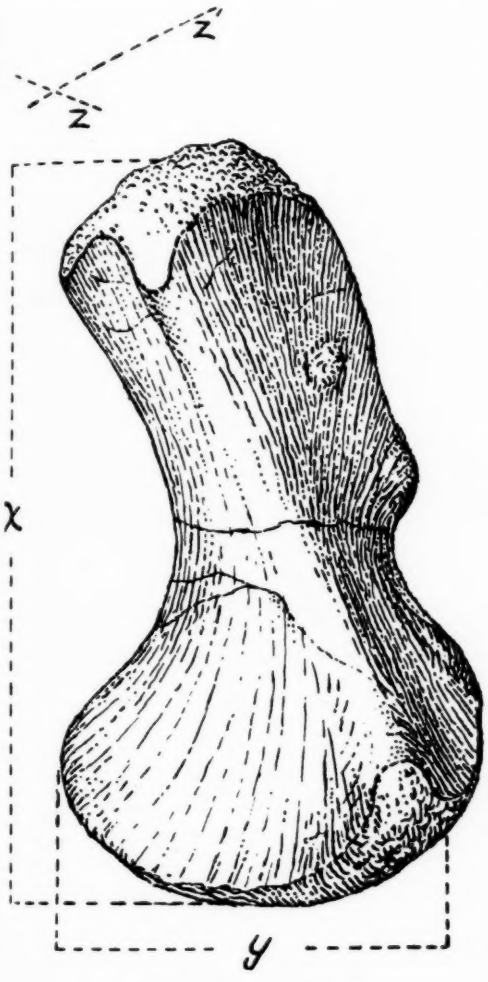

FIG. 1—Right humerus #7.

the assumption that the variates are normally distributed and their relationship linear, a coefficient of correlation has been calculated for each set of values (see table 2). All are positive and fairly high, ranging from 0.84 to 0.96. Their significance has been tested by calculating values of t. The corresponding tabular values of P (<0.01) for each bone establish Y as a function of X in the population represented.

RELATIVE GROWTH

The growth of bone is complicated by the accompanying phenomenon of resorption. In general, however, it is accomplished by additions to the exterior; and these fossils

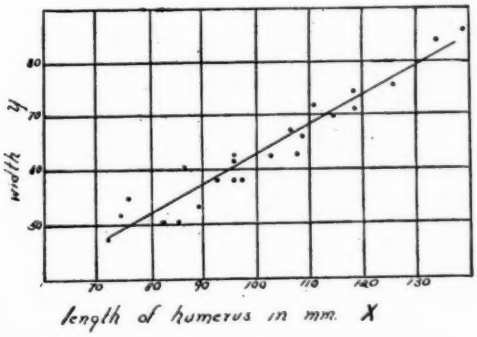

FIG. 2—Regression of distal width on length.

show a finely banded, almost lamellar structure of their outermost parts.[1] The heaviest development occurred in peripheral zones subject to maximum stress.

Most biological growth may be described in terms of the straight line equation or of the allometric expression, $Y=bX^k$, both of which tend to obscure small and strictly local changes. Attention must here be confined to the inorganic phase of bone where the effects are seen to have been additive. This does not mean, of course, that more fundamental factors in growth, such as

[1] Such banding, of course, may be taken to indicate periodicity, whether by seasonal growth or by diffusion of calcium salts into their colloidal medium, after the fashion of Liesegang's rings.

divisions of the osteoblasts, may not have been multiplicative in type.

Since the trend of points in the scatter diagrams is linear, their distribution may be expressed in the slope-intercept form of the equation for a straight line, $Y = mX + b$; where m (a pure number) is the rate of change of width with respect to length, and b is the intercept of the line (when produced) on the Y-axis. Such lines may be taken to represent the relative growth of a hypothetical individual. They have been determined by the method of least squares for error in a single variable, and the resulting constants will be found in table 2. Here nothing is said about growth in time, though time remains implicit in every expression of relative growth.

TABLE 2.—REGRESSION OF DISTAL WIDTH ON LENGTH

Element	r	m	b	S_y
humerus	0.96	0.545	8.0	2.9
radius	0.90	0.369	1.0	1.7
ulna	0.84	0.223	5.0	1.5
femur	0.95	0.246	10.0	2.2
tibia	0.89	0.378	6.0	0.8
fibula	0.94	0.494	4.0	2.0

It follows from the concept of a straight line that the ratio between the increments of width and length is a constant ($dy/dx = k$). It will be noted that the slope for the arm exceeds those of the forearm, while the reverse relationship obtains between thigh and shank. One practical use of these regression constants lies in predicting the value of Y to be associated with a given length. Limits to the variation of such a value are given by the standard error of estimate. The biological significance of b is questionable. At most it may suggest the approximate diameter of the cartilage shaft when ossification began. The fact that none of the regression lines passes through the origin demonstrates at once that growth was accompanied by change of shape, i.e., that the growth transformation was not equiangular.

This conclusion has been tested for the humerus by comparing values for a given internal angle, namely, that formed between the line of distal width (Y) and the diagonal ridge which extends from the ectepicondyle to the area of insertion of the latissimus dorsi (see fig. 3). When nineteen values for this angle are plotted against appropriate lengths, it appears to progress slowly through about five degrees, becoming less acute as the amphibian aged. Correlation between the two variates, however, is slight ($r = 0.19$); and a calculation of t fails to establish its significance.

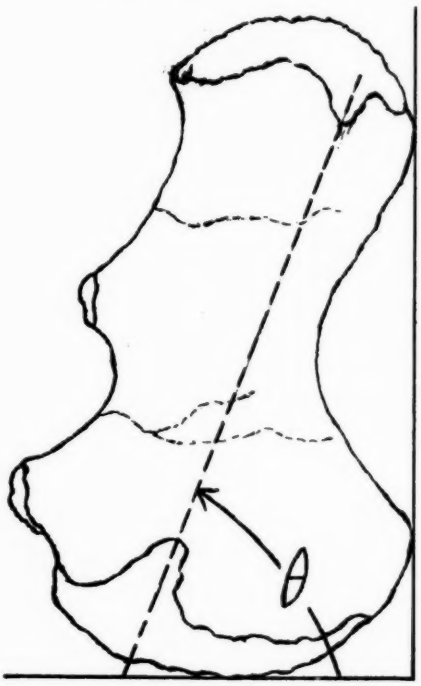

FIG. 3—An interior angle of humerus.

Judged from their outlines in dorsal aspect, the limb bones of *B. perfecta* changed their form with increased size. In the case of the humerus, however, the above measurement of an internal character seems to demonstrate an equiangular transformation. This discrepancy serves to illuminate the earlier statement that general growth equations tend to obscure local change and cannot faithfully reflect the process in detail.

Because growth proceeded in three dimensions a third measurement is necessary to complete the study. This was made along the Z-axis (see fig. 1) at the proximal ends

of both humerus and femur. In the former, because of the angle at which the two fan-shaped extremities are opposed, no single measurement exactly coincides with the stated direction. Therefore two measurements were made perpendicular to one another and recorded as Z and Z' respectively.

The values of Z plotted against length for the femur show a rectilinear trend similar to the previous distributions, and the line of regression again fails to pass through the origin. Plots of Z and Z′ for the humerus actually reveal a curvilinear trend, that for Z′ being slightly more pronounced with increased length or age. This indicates that in the second plane also growth meant change of shape and suggests that, for the humerus at least, such change was especially evident during the latter stages of growth. And since relative growth has now been investigated in three directions, it may be concluded from the varying growth ratios that increased area in plan is not an exactly linear index of added bulk.

Measurements have also been made on the two bony elements of the pelvic girdle, ilium and ischium. Both yield linear plots of the foregoing type with comparably high correlations.

COMPARISONS

Figures published by H. J. Sawin (1945) in his description of related forms from the Dockum Triassic of Howard County, Texas, provide an interesting comparison. By substituting his extreme values for length and distal width of either propodial in the equation

$$\frac{X-X_1}{X_2-X_1}=\frac{Y-Y_1}{Y_2-Y_1}$$

an approximation is obtained to both slope and intercept of the line of regression. These are calculated to be about 0.27 and 8.5, respectively, for the femur. They compare favorably with results secured for *B. perfecta*. Agreement for the humerus, however, is not so close, partly because of the inclusion of one apparently erratic value and also, it seems, from a slight difference in the manner of measuring distal width. Here also, however, the steeper slope is characteristic of the latter element.

For comparison with another group, similar measurements were made on a series of 14 humeri of the Permian rhachitomous amphibian, *Eryops*. Probably because the specimens came from different localities and formations, also because some were badly crushed, no two sets of measurements showed anything approaching uniform variation.

GROWTH IN TIME

In the foregoing discussion of growth as an implicit function of time, it has been assumed that length provides a measure of age. If their histology were better understood, sectional studies of the bone and such qualitative differences as rugosity, extent of finished surface, development of processes, etc., might assist in this determination. As it is, however, the only conclusions justified are (1) that with increased age the proximal end of each propodial became more convex and that (2) their endochondral trabeculae became more regularly oriented with the main axis of the bone in older portions of the diaphysis. The former probably corresponds to change in shape of the cartilage growth zone which provided for terminal expansion of the bony shaft. The latter suggests adjustment in a plastic medium in response to stress. Its incompleteness indicates the lessened importance of mechanical factors in shaping the limbs of a degenerate and secondarily aquatic stock.

There is an obvious distinction between the above discussed growth of parts and that of the organism as a whole. In the latter application of any general growth equation, however, studies of vertebrate fossils are commonly impeded by the want of an entire organism or of any structural unit that can be taken as the independent variable.[2] A further difficulty is present in

[2] Romer and Price (1940), in a study of size relations among pelycosaurs, employed a unit of measurement, r^3_3, in which r is the radius of a typical dorsal vertebra. This unit was subsequently termed "olu" (orthometric linear unit) and applied by the senior author to a demonstration of allometric growth in the same reptilian group. However, like the "cube law" this unit derives from the principle of similitude and is subject to the same restrictions. Because the relation holds only for similar forms, it cannot be used either to compare forms obviously not equiangular or to evaluate the independent variable of a heterogonic function.

the fact that weights are neither available nor readily deduced from existing data. Partial exception to the latter difficulty is afforded, of course, by those rare cases of growth to which the so-called "cube law" properly applies.

It is reasonable to assume, however, that the absolute growth curves of these limbs would be sigmoidal. One immediate consequence is that equal changes in the dependent variable must indicate longer intervals of time as they occur toward the upper asymptote. In other words, the time character must be accelerated so that the second derivative to the curve assumes a negative sign. Accordingly, the various plots of relative growth must be adjusted to show concavity downward before the independent variable can be accepted as a constant measure of time. The rate of change in slope remains a matter for conjecture.

CAUSE AND EFFECT

It is a deficiency of studies restricted to the geometrical aspects of growth that they fail to explain morphological change. Yet apart from their descriptive value, quantitative studies are justified only as they elucidate cause and effect. In this connection a few conclusions may be drawn, especially regarding the humerus, which from the dynamic standpoint is by far the most significant structure here reported. In the lesser angle (about 45°) at which its two fan-shaped extremities are set, may be recognized a reduction of the torsional stress which in the terrestrial *Eryops* served to place those ends in almost rectangular opposition. The growing tendency in later stages toward disproportionate growth of its proximal end may be taken as evidence of an adjustment to secure greater area for muscle insertion. Conversely, the relative growth of the distal end at a merely linear rate shows that with increased age there was no increasingly advantageous insertion of the flexor muscles of the forearm by enlargement of the entepicondyle. The slight change in shape of all the limb bones appears related to the circumstances of aquatic life, where limbs are no longer employed in body support. In general, conclusions based on the size relations of these bones confirm the view that *B. perfecta* was a shallow water form descended from terrestrial stock.

CONCLUSIONS

1. The form of the limb bones in *Buettneria perfecta* was established early in life. Subsequent growth increased their size with but little change in shape.

2. The relative growth rate varied somewhat from bone to bone and with the direction taken.

3. Change in form of the humerus failed to affect at least one internal angle.

4. In general, measurements confined to a plane are inadequate to describe the three-dimensional growth of such bones.

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JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 4, PP. 525–526, 1 TEXT FIG., JULY 1951

A NEW INSTRUMENT FOR MEASURING FOSSILS

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DURING the study of a group of Paleozoic gastropods the writer designed an instrument to increase the precision of his measurements. After its construction he discovered that somewhat similar work had been done before (Thompson, 1917; Stuart, 1927) but it is believed that this instrument is more accurate and more widely applicable to a variety of problems than those previously designed. It should be of value in measuring any fossils within its size limitations, particularly those with some form of radial symmetry such as crinoids, cystoids and blastoids, and even small vertebrae.

This instrument consists essentially of a revolving graduated stage with vertical and horizontal graduated scales which can locate any point on the surface of an object in three dimensional coordinates. Measurements can be made accurately to less than 0.05 mm. on the horizontal and vertical scales and 0.5° on the rotating stage. Extreme ranges of the three scales are: 360° rotation for the stage, 13.5 mm. for the horizontal radius, and 25 mm. on the vertical scale. Two Brown & Sharpe metric micrometer heads are used for the horizontal and vertical measurements and a discarded petrographic microscope furnished the base and stage. The vertical micrometer is mounted in a brass block sliding between two vertical posts of drill rod and carries the horizontal micrometer with it. In order to reduce friction the anvil of the vertical micrometer is supported by a steel ball in a cup attached to the base and the entire assembly is spring loaded so that the anvil remains in contact with the ball. The anvil of the horizontal micrometer pushes a spring loaded plunger bearing the measuring point. Screws for centering the stage and changing the position of the horizontal and vertical micrometers to compensate for wear were added. For other features of construction see figure 1.

To mount a specimen for measuring, the axis of the specimen is determined and one end of the axis is placed on the pin in the center of the rotating stage. Plasticine is then built up around the specimen until it is stable. The horizontal micrometer is set on zero (i.e., the measuring point is brought to the center of the rotating stage) and the vertical micrometer is used to bring the measuring point down to just above the specimen. The stage is then rotated and deviation of the upper end of the axis of the specimen is noted under a hand lens and corrected.

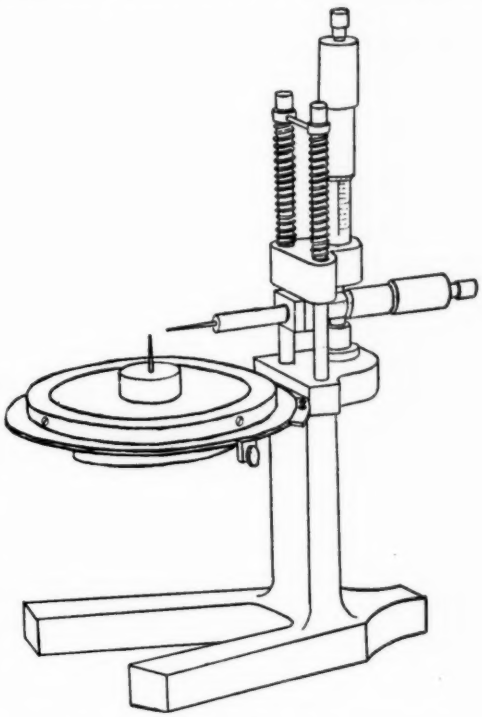

FIG. 1—Perspective view of the instrument.

Coordinates of points on the surface are expressed in terms of Z, ρ, θ, representing vertical coordinates measured on the vertical micrometer, radial coordinates measured from the axis on the horizontal micrometer, and angles measured on the rotating stage. In comparing different specimens, coordi-

nates of a reference point are measured and used as an origin. The choice of an origin may be purely arbitrary or may be governed by the morphology of the specimen. In the case of normal trochoform gastropods the top of the protoconch should be chosen as the origin with the umbilicus located on the center pin of the stage. Measurements of any particular series of points that appear to be significant are taken and referred to the origin by subtracting the value of *Z* for the origin from the value measured. Because of the delicacy of the micrometer all measures should be made under a hand lens in order that the orientation of the specimen may not be disturbed.

Measurements can be made with a precision not generally attempted in the past and they can be treated analytically as a series of points in space. Interrelations between different sets of measurements are included implicitly in the data. For example, angles between differently orientated linear measurements are furnished.

The precision of the instrument has been tested by making 30 consecutive measurements on each of the three scales independently. The standard error of measurement was found to be 0.021 mm. on the vertical scale, 0.018 mm. on the horizontal scale, and 0.28° on the stage.

Encouragement and advice were generously given by Dr. E. C. Olson and Dr. J. M. Weller in this project. The writer is also indebted to W. F. Schmidt and M. Rubin for construction of the instrument and for many features of the design.

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JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 4, PP. 527–530, JULY 1951

NEW GENERA AND SUBGENERA OF RADIOLARIDA

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ABSTRACT—Two new genera, six new generic names and three subgeneric names of Recent and fossil Radiolarida are herein proposed. These result from an intensive examination of the literature.

THE taxonomy of the Radiolarida as a whole has not been subjected to rigid examination for many years and a review of the extensive literature devoted to these protozoans, of which 884 fossil and Recent genera and 709 subgenera have been described, has revealed several that appear to require new names and further definitions. The necessity for new names results from the misinterpretation of older genera by Haeckel and Rüst, the introduction of names with more than a single definition by Haeckel and the circumstances in which the Rules of Nomenclature have not been followed by Haeckel. Eleven new generic and subgeneric names are proposed. Type species of these genera are designated.

Only two references are cited. Others may be found in the extensive bibliography of Haeckel (1887).

Genus CALOSPHAERA Campbell, nom. nov.

=*Thalassosphaera* HAECKEL 1887, p. 30; not *Thalassosphaera* HAECKEL 1862, p. 260.

Description.—Thalassosphaeridae without alveoles and with simple, unbranched, needle-shaped spicules within the calymma.

Type species.—*Thalassosphaera belonium* Haeckel 1887, p. 31 (not figured). Recorded at Challenger station 272 at the surface in the central Pacific.

Discussion.—Haeckel (1887, p. 31) stated,

> I here confine the genus *Thalassophaera* to those Beloidea in which the body exhibits no alveoles, and the siliceous, solid spicula in the calymma are quite simple needles.

At the same time he excluded *Sphaerozoum bifurcum* Haeckel 1860 (p. 845), referred to *Thalassophaera* Haeckel 1862, from the genus and placed it in the subgenus *Thalassoxanthomma* Haeckel 1887 (p. 33) of the genus *Thalassoxanthium* Haeckel 1887 (p. 31). The only other species included in *Thalassophaera* by Haeckel in 1862 was *Thalassicolla morum* Müller 1858, a species which was later redescribed as *Calcaromma calcarea* by Thompson, 1877 (p. 233). This may not be a radiolarian or it may be a true *Thalassicolla*. Haeckel believed it might be a species of his *Actissa* Haeckel 1887 to which calcareous bodies of several sorts are adherent.

In spite of its removal in 1887 *Sphaerozoum bifurcum* is the only undisputed member of *Thalassosphaera* and the 1887 description of the genus does not agree with its characters since its spicules are branched or compound rather than simple needles. A new name for the group for which Haeckel used the name *Thalassosphaera* in 1887 is required.

The characters of *Sphaerozoum bifurcum* are those upon which *Thalassoxanthium* Haeckel 1887 (p. 31) was based and this name is a junior synonym of *Thalassosphaera*. The type species is *Thalassosphaera bifurca* (Haeckel). *Thalassoxanthomma* Haeckel 1887 is a second junior synonym of *Thalassosphaera*.

Calosphaera differs from *Thalassosphaera* Haeckel 1862 in having simple instead of branched or compound spicules, and from *Physematium* Meyen 1834 in not having alveoles in any part of the cell.

Genus THALASSORHAPHIS Campbell nom. nov.

=*Thalassoplancta* HAECKEL 1887, p. 36; not *Thalassoplancta* HAECKEL 1862, p. 261, and 1881, p. 470.

Description.—Thalassosphaeridae with numerous large alveoles in the calymma and not in the central capsule; with numerous unbranched solid needle-like spicules around the central capsule.

Type species.—*Thalassoplancta brevispicula* Haeckel 1887, p. 36, pl. 2, fig. 2, =*Lampoxanthium brevispiculum* Haeckel

1882, Mss., 1887. Recorded at Challenger station 334 at the surface in the south Atlantic.

Discussion.—Haeckel (1887, p. 36) stated

> The genus *Thalassoplancta* was founded by me in 1862 for a Radiolarian with simple hollow needles in the calymma, which was afterward recognized as a phaeodarium, belonging to *Cannorrhaphis*. We retain this name for a true Thalassosphaerid, very similiar to the latter, but distinguished by the absence of the phaeodium and the solid—but not hollow—needle-like spicula, which are scattered in the alveolated calymma.

In 1862 *Thalassicolla calvispicula* Haeckel 1860 (p. 789) was the only species of the genus *Thalassoplancta* which was, therefore, monotypic. Haeckel's redefinition in 1887 cannot be accepted and a new name is demanded for this very different genus which clearly belongs to the simple Spumellina.

Haeckel placed *Thalassicolla calvispicula* in his new genus *Cannobelos* which he erected in 1887. This genus, in consequence, is a junior synonym of *Thalassoplancta*. He correctly included *Thalassoplancta* in the Phaeodarina in his 1881 paper.

Thalassorhaphis has simple needle-like spicules around the central capsule, unlike *Lampoxanthium* Haeckel 1887. It differs from *Thalassosphaera* Haeckel 1862 in having alveolated cytoplasm. *Physemantium* Meyen 1834 differs in having alveoles confined to the central capsule.

Genus THECOTAPUS Campbell, n. gen.

=*Thecosphaera* RÜST 1885, p. 292(22).

Description.—Liosphaeridae with two concentric cortical shells and a single medullary shell, the inner cortical shell having large circular pores and delicate frames.

Type species.—*Thecosphaera unica* Rüst 1885, p. 292 (22, pl. 29 (4), fig. 8. Monotypic. In Jurassic jasper in Switzerland.

Discussion.—This genus differs from *Thecosphaera* Haeckel 1881 in having two cortical shells and one solitary medullary shell whereas the latter genus has two medullary shells and a single cortical shell. Also the pores of the innermost and outermost of the three shells are small but those of the inner cortical or second shell are large and within frames. The single figure of a thin section given by Rüst is schematic but does show the essential characters.

The new genus differs from *Rhodosphaera* Haeckel 1881 in the character of the pores of the middle shell.

Genus PHYLETRIPES Campbell, n. gen.

=*Hexastylus* RÜST 1885, p. 289(19); not *Hexastylus* HAECKEL 1881, p. 450.

Description.—Triposphaeridae with one single, smooth, lattice-sphere having three short, blunt, equidistant radial spines.

Type species.—*Hexastylus primaevus* Rüst 1885, p. 289 (19), pl. 28 (3), fig. 3. Monotypic. Found in hornstone of the lower Liassic at Csernye, Hungary and also in the black hornstone at Rigi, Switzerland.

Discussion.—Rüst's species does not fit the original description of *Hexastylus* in that he clearly stated that it has three instead of the six radial spines explicitly mentioned by Haeckel.

This genus is the only one of the Triposphaeridae with a single lattice-sphere, all of the four others having two or more concentric shells. They also regularly have three radial spines.

Genus EULOPHOSPYRIS Campbell, nom. nov.

=*Lophospyris* HAECKEL 1887, p. 1080; not *Lophospyris* HAECKEL 1881, p. 443, and 1887, p. 1066.

Description.—Tholospyridae with two basal lateral feet and an apical horn.

Type species.—*Lophospyris diplodiscus* Haeckel 1887, p. 1080, pl. 95, fig. 14. Recorded at Challenger station 225 in the western tropical Pacific at 4475 fathoms.

Discussion.—In 1887 Haeckel used *Lophospyris* twice for different members of the Nassellina. On page 1066 it designates a subgenus of *Ceratospyris* Ehrenberg 1847, and it again appears on page 1080 where it is termed sensu emendato, as a genus. Haeckel 1881 (p. 443) originally defined the genus as follows, "Polyspyrida acuta cum spina apicali, ramis liberis." This description seems to conform with his usage on page 1066, and *Lophospyris* should be retained as a subgenus of *Ceratospyris*. For this subgenus we designate *Ceratospyris pentagona* Ehrenberg 1872, pl. 10, fig. 15, as the type species.

The related *Tholospyris* Haeckel 1881 has three lateral basal feet.

Genus HALIPHORMARTIDIUM Campbell, nom. nov.

=*Haliphormis* HAECKEL 1887, p. 1166; not *Haliphormis* EHRENBERG 1847, p. 54.

Description.—Phenocalpidae with numerous ribs in the wall of the bell-shaped shell prolonged into free terminal feet. The apex has a horn.

Type species.—*Haliphormis lagena* Haeckel 1887, p. 1167, pl. 97, fig. 5. Recorded at Challenger station 332 in the south Atlantic at 2200 fathoms.

Discussion.—Ehrenberg's (1847, p. 54) description of *Haliphormis* was brief and generalized and it was not until 1854 that he included *H. calva* (p. 66) in the genus, and later included *H. hexacantha* (1872, p. 294, pl. 10, fig. 16—labelled 6 on the plate explanation). Haeckel (1887, p. 1166) used the name *Haliphormis* sensu mutato, explaining that the few forms included by Ehrenberg are not recognizable or belong partly to other genera. Haeckel (1881, p. 428) had already given the genus a new definition which was that used by him in 1887 (p. 1166) and it is therefore obvious that a new name is required for the group he had in mind.

The related *Archiphormis* Haeckel 1881 has no horn and *Cystophormis* Haeckel 1887 has no free feet.

Subgenus DIMELISSA Campbell, nom. nov.

=*Micromelissa* HAECKEL 1887, p. 1205, =*Sethomelissa* HAECKEL 1887, pl. 56, fig. 1; not *Micromelissa* 1881, p. 433, nor *Sethomelissa* HAECKEL 1881, p. 431.

Description.—*Lithomelissae* having the cephalis with two divergent apical horns, one superior occipital horn and the other an inferior frontal horn.

Type species.—*Lithomelissa thoracites* Haeckel 1862, p. 301, pl. 6, figs. 2–8. Cosmopolitan in the Mediterranean and in the Indian and Pacific Oceans.

Discussion.—In 1887 Haeckel used the name *Micromelissa* twice for very different Radiolarida. First it was considered a subgenus of *Lithomelissa* (p. 1205) and later (p. 1235) an independent genus. The former was stated to be in sensu emendato. The genus as originally constituted (Haeckel, 1881, p. 433) included only basally fenestrated Dicyrtoidea but *Lithomelissa* is basally open. A new name therefore is needed for Haeckel's subgenus.

Haeckel (1887, pl. 56, fig. 1) designated one of his figured specimens *Lithomelissa bütschlii*, n. sp. vel *Sethomelissa bütschlii*, n. sp., but he listed it among the species of *Micromelissa* sensu emendato. His second figure (1887, pl. 56, fig. 2) is labelled *Lithomelissa decacantha* n. sp. vel *Sethomelissa decacantha*, n. sp., but is included in the text in the subgenus *Sethomelissa* Haeckel 1881.

Dimelissa differs from the typical subgenus, *Lithomelissa*, by having two apical horns instead of a single one.

Subgenus CORYTHOMELISSA Campbell, nom. nov.

=*Sethomelissa* HAECKEL 1887, p. 1207; not *Sethomelissa* HAECKEL 1881, p. 431.

Description.—*Lithomelissae* having the cephalis with three, four or more apical horns including a primary or occipital horn, a secondary or frontal horn, and one or more accessory or parietal horns.

Type species.—*Lithomelissa corythium* Ehrenberg 1875, p. 78, pl. 3, fig. 12. Recorded at Challenger station 268 in the central Pacific at 2900 fathoms and in the upper Eocene of Barbados.

Discussion.—In 1887 Haeckel used the name *Sethomelissa* twice for very different Radiolarida. First it was considered a subgenus of *Lithomelissa* (p. 1207) and later (p. 1237) an independent genus. In Haeckel's earlier paper (1881, p. 431) the genus was clearly defined as, "Dicyrtida aperta triradiata," but later (1887, p. 1237) was stated to be "Dicyrtoidea triradiata clausa." The intent of the first definition is clear but the second one is an obvious error. A new name is required for the species described on pages 1207 and 1208 of the Challenger Report. Besides its type the subgenus includes *Lithomelissa* (*Sethomelissa*) *decacantha* Haeckel 1887.

Corythomelissa may be distinguished from the other subgenera of *Lithomelissa* by the more numerous apical horns.

Genus ARTOPERINA Campbell, nom. nov.

=*Artopera* HAECKEL 1887, p. 1452; not *Artopera* HAECKEL 1887, p. 1450, nor *Artopera* HAECKEL 1881, p. 438.

Description.—Podocampidae with basally fenestrated shell and three solid lateral wings or ribs. On the pointed end of the last joint is a vertical spine. The cephalis bears an apical horn.

Type species.—*Lithornithium loxia*

Ehrenberg 1854, pl. 36, fig. 8. It is also figured by the same author in 1875 (pl. 4, fig. 8). Upper Eocene of Barbados.

Discussion.—Haeckel (1881, p. 438) defined *Artopera* as "Tetracyrtida clausa triradiata, costis, tribus lateralibus clathratis." This characterization clearly states that the shell possesses latticed and not solid, lateral wings or ribs. Consequently, Haeckel's first usage of the name in 1887 (p. 1450) as a subgenus of *Cyrtopera* Haeckel 1881 is correct, but the second usage (p. 1452) for forms with solid and not latticed wings or ribs is not, and a new name is needed for the latter group of beautiful and familiar species. Haeckel (1887) described two additional species from the Challenger collections besides the type.

This genus differs from *Stichopera* Haeckel 1881 in lacking longitudinal combs and is distinguished from *Cyrtopera* Haeckel 1881 by the solid rather than latticed wings or ribs.

Subgenus PHORMOSTICHOARTUS Campbell, nom. nov.

=*Acanthocyrtis* HAECKEL 1887, p. 1461; not *Acanthocyrtis* HAECKEL 1881, p. 437, nor 1887, p. 1494.

Description.—*Cyrtophormis* having the shell with numerous (12 to 20 or more) terminal feet.

Type species.—*Cyrtophormis* (*Acanthocyrtis*) *cylindrica* Haeckel 1887, p. 1461, pl. 77, fig. 17. Recorded at Challenger station 271 at 4475 fathoms in the central Pacific.

Discussion.—In the original publication (Haeckel, 1881, p. 437) *Acanthocyrtis* was placed adjacent to *Eucyrtidium* (which genus was marked by an asterisk indicating a new genus!) and stated to be distinguished by "testa spinosa," whereas *Eucyrtidium* was stated to be characterized by having "testa laevi." In 1887 Haeckel (p. 1461) used the name *Acanthocyrtis* first as a subgenus of *Cyrtophormis* Haeckel 1887 stating, "shell with numerous (12–20 or more) terminal feet," and again later (p. 1494) he used it as a subgenus of *Eucyrtidium* Ehrenberg 1847 where it was differentiated as having "Joints of the shell of very different lengths. Surface spiny." It is apparent that the later description is more nearly in keeping with the original intent of the description of *Acanthocyrtis* and this name should be retained for a subgenus of *Eucyrtidium*. For the other group a new name is needed.

The typical subgenus of *Cyrtophormis* has five to seven terminal feet in contrast with the greater number in this subgenus.

Genus GLYCOBOTRYS Campbell, nom. nov.

=*Lithobotrys* HAECKEL 1887, p. 1117; not *Lithobotrys* EHRENBERG 1844, p. 74.

Description.—Botryopylidae with tubules on the cephalis and with the basal mouth of the thorax fenestrated.

Type species.—*Lithobotrys geminata* Ehrenberg 1875, p. 76, pl. 3, fig. 19. Upper Eocene of Barbados.

Discussion.—Ehrenberg in 1844 named *L. quadriloba* (p. 84) as the first species to be included in his *Lithobotrys* which was listed on a previous page (p. 74) in the same publication. This is, therefore, the type species of the genus. Haeckel, however, in 1887 included this species and several others in his new genus *Botryopera* which is consequently a junior synonym of Ehrenberg's genus. He stated (p. 1117),

> The numerous species described by Ehrenberg belong to very different genera of Botryoidea, and partly also of Spyroidea. Following Bütschli (1882) we retain here the name *Lithobotrys* for those species, the type of which is *Lithobotrys geminata*.

This latter species cannot be the type of *Lithobotrys* since it was not originally included in the genus in which there was already one species. It is apparent that Haeckel's *Lithobotrys* is not Ehrenberg's and a new name is required for those species which the former placed in the genus.

Glycobotrys is basally fenestrated whereas *Acrobotrys* Haeckel 1881 is not. *Botryocella* Haeckel 1881, which has a closed thorax, is without cephalic tubules.

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RÜST, D., 1885, Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen des Jura: Palaeontologica, vol. 31, pp. 269–322, 20 pls.

JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 4, PP. 531–532, JULY 1951

NOTES ON THIN SECTIONING OF SMALLER FORAMINIFERA

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RECENT work by the writer in the thin sectioning of smaller Foraminifera has resulted in the development of a technical routine that may be of interest to others.

Following the suggestions of Meyer (1946) and Levinson (1950), thermoplastic No. 70, produced by Lakeside Chemical Corporation of Chicago, was used for mounting. This material is available in inexpensive bars 9×15×183 mm. in size and 35 gr. in weight. It has the following properties: it melts quickly above 80°C.; it requires no cooking and becomes a strong, solid mass on cooling; it is soluble in acetone, chloroform, Cellosolve (ethylene-glycol-monoethyl-ether, produced by the Carbide and Carbon Corporation of New York), and more slowly in alcohol; it may be cooled very quickly without becoming brittle; it has a refractive index of 1.54, similar to Canada balsam; it is practically colorless in thin films.

The following abrasives were used in grinding and found to be equally effective: Bausch and Lomb's Corundum 2600, M-5 Microabrasive, produced by Metal Finishing Service of Chicago, and levigated alumina, produced by the Norton Company of Worcester, Massachusetts. Grinding materials coarser than 2500 mesh were found unsatisfactory.

The sectioning of empty specimens requires the following steps:

1. A specimen is placed on a hollow-ground glass slide with a few drops of solvent for at least one minute.

2. The tip of a stick of thermoplastic is held very close to a gas flame for a few seconds until it melts and two drops fall on another hollow ground slide.

3. This slide is warmed on the hot plate and when the thermoplastic melts the specimen is removed from the solvent and placed in it.

4. The slide is kept on the hot plate until bubbling at the surface of the specimen stops. This shows that the solvent has completely evaporated and been replaced by the thermoplastic. About 30 to 90 seconds are required, depending on the temperature, the inner structure of the specimen, etc.

5. An ordinary glass slide is placed on the hot plate, touched with a stick of thermoplastic and quickly moved to an asbestos sheet under the microscope.

6. The specimen is transferred from the hollow ground slide to the new slide and properly oriented with a hot needle.

7. The slide is placed on the grinding glass and moved around a little to speed up cooling.

8. The grinding operation is performed according to the usual technique until the plane of the desired section is reached.

9. The slide is washed, dried, heated on the hot plate, transferred to the asbestos sheet under the microscope and the specimen is turned over with a hot needle.

10. The grinding process is continued until finished.

11. The slide is washed and examined under the microscope. If bubbles are present in the thermoplastic, they can be removed by warming a little or applying a drop of solvent with a medicine dropper and then speeding evaporation of the solvent by moderate heating.

12. A cover glass is applied and the slide cooled. The cover glass may be cemented with Canada balsam, according to the usual technique. Balsam has a melting point lower than that of the thermoplastic and, therefore, this operation can be performed without disturbing the specimen.

If fossils are completely filled inside, steps 1 to 4 are unnecessary.

If a thin section is to be photographed, this may be done before the cover glass is applied, thus avoiding the possibility of accidents. The surface of the specimen should be moistened with immersion oil or

glycerin, both of which are non-drying and have a refractive index close to that of the thermoplastic.

Acetone, if used as the solvent, evaporates very quickly and leaves a whitish emulsion of microscopic bubbles, but these can be eliminated by heating the slide. Chloroform evaporates less quickly and rarely produces an emulsion. Somewhat slower still is Cellosolve which, in the writer's experience, has never produced an emulsion and seems to be the most convenient solvent. Alcohol is much too slow.

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LEVINSON, S. A., 1950, A technique for sectioning microfossils: Science, n.s., vol. 111, p. 60.

JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 4, PP. 533–536, 2 TEXT FIGS., JULY 1951

PALEONTOLOGICAL NOTES

CAMBRIAN TRACKS IN THE LAMOTTE SANDSTONE

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In 1947 Mr. James Snider, a graduate student at the Missouri School of Mines, brought to me for identification several sets of tracks in a sandstone slab. Professor G. A. Muilenburg, who is well acquainted with the geology of the region, kindly gave assistance in establishing the position of the outcrop from which the slab had been taken. It is in a small highway cut on the north side of Missouri State Highway 70, about 7 miles west of Fredericktown (NE NW SE, sec. 8, T. 33 N., R. 6 E.).

The tracks were found on a surface of a lens of medium-grained, well sorted, cross-bedded, rather clean sandstone in the Lamotte formation. The sandstone lens is set off in the section by its clean character as compared to the clayey, poorly sorted, arkosic, yellow, buff and red beds below it. Nearby are outcrops of pre-Cambrian igneous rocks. The position of the sandstone bed and the character of the lithology suggest that the fossil horizon lies in the lower part of the Lamotte sandstone.

The slab (fig. 1) shows well developed tracks which are identified as *Climactichnites* sp. Logan and *Protichnites* sp. Owen. There are three sets of *Climactichnites*, two approximately parallel, crossed by the third at about right angles. The tracks of *Protichnites* are less well developed and seem to be overrun by the youngest of the *Climactichnites*. There are, however, three areas where fragments of the *Protichnites* tracks are identifiable. Unfortunately, at the time the outcrop was examined, the area of visible bedding surface was too limited to reveal further information concerning the origin of the tracks. It is interesting, however, that the left hand vertical *Climactichnites* track does not have a continuous impression from side to side as do the others, and that the two sides seem to diverge as the track continues toward the top of the slab.

The only fossils previously reported for the Lamotte sandstone are *Obolus lamborni* (Meek) and a few imperfectly preserved trilobite fragments (Weller and St. Clair, 1925). This slab, therefore, offers the first well preserved fossil evidence of the age of the Lamotte sandstone. The occurrences of *Protichnites* and *Climactichnites* are limited to the lowest formation of the Upper Cambrian, notably the Potsdam sandstone of the New York area (Owen, 1852; Logan, 1860) and the Mount Simon sandstone of the Wisconsin area (Todd, 1882). In Resser's (1935) list of fossil zones for the Upper Cambrian, the lowermost zone is designated as the *Climactichnites* zone. If the zonal designation for this genus is valid, the Lamotte sandstone can be correlated with the Mount Simon sandstone of Wisconsin and the Potsdam sandstone of New York by direct paleontological evidence.

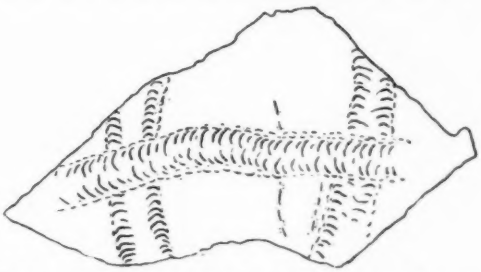

FIG. 1—Sketch of slab of Lamotte sandstone showing *Climactichnites* and *Protichnites* tracks; ×4.

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LOGAN, W. E., 1860, On the tracks of an animal lately found in the Potsdam formation: Canadian Naturalist and Geologist, vol. 5, pp. 279–285, figs. 1–5.

OWEN, RICHARD, 1852, Description of the impressions and footprints of *Protichnites* from the Potsdam sandstone of Canada: Geol. Soc. London Proc., vol. 8, pp. 214–225, pls. 6–14.

RESSER, C. E., 1938, The Cambrian system (restricted) of the southern Appalachians: Geol. Soc. America Special Paper 15, p. 20, table 1.

TODD, J. E., 1882, A description of some fossil tracks from the Potsdam sandstone: Wisconsin Acad. Sci., Arts and Letters, vol. 5, pp. 276–281, pl. 1.

WELLER, S., and ST. CLAIR, S., 1928, Geology of Sainte Genevieve County, Missouri: Missouri Bur. Geology and Mines, 2nd ser., vol. 22, p. 38.

CIBICIDES OR *EPONIDES COCOAENSIS* CUSHMAN

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In compiling a set of species index cards for guide fossils of the Atlantic Coast the author discovered irregularities in the descriptions of *Eponides cocoaensis* Cushman. This species is restricted to the Jackson Eocene so far as published records indicate, and its index value indicates that its status should be clarified. The inconsistencies were discovered after publication of the author's recent work, "A summary of the foraminiferal guide fossils of the Atlantic Coastal Plains region between New Jersey and Georgia," in which the name *Eponides cocoaensis* Cushman should be replaced by *Cibicides cocoaensis* (Cushman) Bandy, and the description by Bandy (1949, p. 103) should be substituted for that of Cushman (1935, p. 47).

The transfer from *Eponides* to *Cibicides* is necessitated by the apertural characters. All examined specimens, including the type, reveal the aperture to be looped over the slight keel rather than restricted to the ventral side as originally stated by Cushman (1928, pp. 73, 75).

The author learned of the apertural characters of the original *Eponides cocoaensis* from Miss Ruth Todd of the Cushman Laboratory for Foraminiferal Research, who reported (personal communication):

> I have looked at the holotype of "*Eponides cocoaensis*" together with the two specimens figured in Prof. Paper 181 (Pl. 19, figs. 1, 2). Although, as you can see, the relative thicknesses of the tests vary considerably, still I would not consider them different, as in their other characters they are quite similar. The holotype also shows the slight keel as do the ones in Prof. Paper 181. I have also looked at a slide of numerous paratypes and a similar variation is evident among them.
>
> As to the aperture; I have reexamined the holotype and it seems to show quite definitely the slight looping over onto the dorsal side as is well shown in Prof. Paper 181 (pl. 19, fig. 2). As the aperture is not widely open, this actual looping over might well have been unnoticed, particularly in the early days of the study.

Miss Todd replied to a letter by the author in which the following differences between the figures in Professional Paper 181 and the original description of *Eponides cocoaensis* were pointed out:

1. Figures 1 and 2, plate 19, show the test notably more slender than in the original.
2. Contrary to the original, the figures in Professional Paper 181 show a definite keel.
3. The chambers figured in Professional Paper 181 seem to be more distinct than in the original.
4. The aperture shown in figure 2, plate 10, loops over the peripheral keel.

In general, Bandy's illustrations of *Cibicides cocoaensis* are similar except that the test is notably thicker.

The author concurs with Miss Todd's observation of the apertural characters of the original *Eponides cocoaensis*, and he agrees with Bandy that this definitely places the species in *Cibicides*.

Statements on page 47 of Professional Paper 181 appear to be the source of error, and these are repeated verbatim by Bergquist (1942, p. 87). This erroneous description does not fit either *Eponides cocoaensis* as originally described by Cushman or *Cibicides cocoaensis* as redescribed by Bandy. This error, which persisted for at least 14 years without detection, indicates the too ready acceptance of figures at the expense of written descriptions.

Descriptions and figures subsequent to the original ones by Cushman apparently do not indicate two bosses on the ventral side as mentioned by Dr. Cushman, nor do they record the same apertural characters. Cushman's dimensions for *Eponides cocoaensis* are slightly smaller than Bandy's. Miss Todd failed to discover the source of the erroneous description appearing in Professional Paper 181, and the author agrees with her that this description should be ignored unless it can be applied to another species. Figures 1 and 2, plate 19, of Professional Paper 181, however, are valid illustrations of *Eponides cocoaensis*.

Bergquist's figures of *Eponides cocoaensis* (1942, pl. 8, figs. 34, 35) show a somewhat lobulate periphery, but as no apertural view is presented and the description is erroneous

they can be identified with this species only provisionally. The figures of *Eponides cocoaensis* in Professional Paper 181 also show a slight peripheral lobulation in the final portion, and it is likely, therefore, that the description of *Cibicides cocoaensis* (Cushman) Bandy should be modified to include specimens with a slight lobulation in the final portion of the tests.

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BERGQUIST, H. R., 1942, Scott County fossils (Illustrated by M. L. Pegues): Mississippi Geol. Survey Bull. 49, pp. 1–146.

CUSHMAN, J. A., 1928, Additional Foraminifera from the upper Eocene of Alabama: Cushman Lab. Foram. Research Contr., vol. 4, p. 73, pl. 10, figs. 2a–c.

——, 1935, Upper Eocene Foraminifera of the southeastern United States: U. S. Geol. Survey Prof. Paper 181.

MCLEAN, J. D., JR., 1949, A summary of the foraminiferal guide fossils of the Atlantic Coastal Plains region between New Jersey and Georgia. Privately printed.

Eponides cocoaensis is also listed or figured in the following publications:

KELLEY, 1943, Am. Assoc. Petroleum Geologists Bull., vol. 27, pp. 8, 11 (lists); MARTIN, 1943, Stanford Univ. Pub., Univ. ser., Geol. Sci., vol. 3, no. 3, p. 10 (list); CUSHMAN and HERRICK, 1945, Cushman Lab. Foram. Research Contr., vol. 21, p. 69; CUSHMAN, 1946, idem, Special Pub. 16, p. 34, pl. 6, fig. 16; DE VLETTER, 1946, Thesis, Univ. Utrecht, p. 50 (list); CUSHMAN, 1948, Maryland Dept. Geology, Mines and Water Resources, p. 240, pl. 19, fig. 21.

COMMENTS ON "TRENDS IN RESEARCH AND THE JOURNAL OF PALEONTOLOGY"

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Based upon a classification of the general fields of research reflected by papers in the 1939 and 1949 volumes of the Journal of Paleontology, George Gaylord Simpson (1950, pp. 498–499) concludes that no trend of study deviating from descriptive morphology and systematics toward work involving a wider scope, either in geology or in biology, seems apparent in the contents of the two volumes. This leads Dr. Simpson to raise the question whether this lack of change reflects conservatism of paleontological research as a whole or only of the papers published in this *Journal*.

It is partly the purpose of these comments to offer an answer to this question by a similar check of papers published in another paleontological periodical in the same years. The writer has chosen a publication with which he has been familiar for a number of years, and which also includes papers reflecting a high level of research whose development was not greatly impaired by war during the decennium under consideration. The results of classification of the general fields of research included in the "Bericht der Schweizerischen Paläontologischen Gesellschaft" (published in the Eclogae Geologicae Helvetiae) are given below. A few fields of paleontological study not represented by papers in both years are omitted.

	1939	*1949*
Descriptive morphology and systematics	6½	9⅔
All others	½	6⅓
Break-down of "all others":		
Mainly geological		
Stratigraphy, correlation	0	5⅔
Sedimentation, preservation	0	⅓
Mainly biological		
Phylogeny	0	⅓
Functional morphology	½	0

The apparent widening of the scope of research combined with a simultaneous increase of descriptive and systematical work shown by these figures will also be revealed if similar checks of papers included in the "Bericht" in years immediately preceding those under consideration are made.

With respect to Dr. Simpson's question whether the "conservative nature" (p. 499) of the Journal of Paleontology should be

regarded as desirable or not, the writer cannot agree with calling the nature of this publication conservative. He believes that paleontology is in very great need of detailed morphologic analysis as an indispensable basis for morphogenetics, study of variability, taxonomy, ecology and biostratigraphic zonation. Fortunately, several papers representing this trend toward observation, description and illustration of morphologic detail have been published in this *Journal* lately, particularly in the field of foraminiferal research. They contrast favorably with the routine descriptions of fossils that still constituted the bulk of micropaleontological literature a decade ago.

REFERENCE

SIMPSON, GEORGE GAYLORD, 1950, Trends in research and the Journal of Paleontology: Jour. Paleontology, vol. 24, pp. 498–499.

CAMPODUS VARIABILIS (MEEK & WORTHEN) FROM THE VIRGILIAN SERIES OF IOWA

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Several specimens of teeth recovered from the Pearson Mine at Clarinda, Iowa, were submitted to us by Mr. George Evans, Mine Engineer. Robert H. Denison of the Chicago Natural History Museum has identified them as *Campodus variabilis* (M. & W.). This genus belongs to the Edestidae, a family of uncertain affinities, although it is generally referred to the Bradyondonti or Hybodontoidea.

St. John and Worthen (1875) and Nielson (1932) refer this species to the genus *Agassizodus*, but Denison (personal communication) informs us that this name is a synonym of *Campodus*.

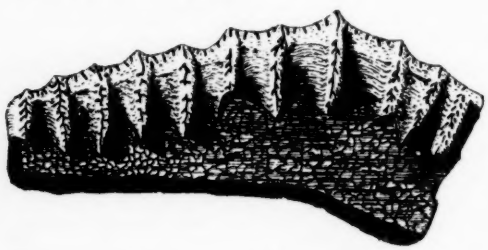

FIG. 1—*Campodus variabilis* (Newberry & Worthen). View of anterior face of an incomplete specimen; ×1. Tooth belongs to median row of acuminate teeth of the right ramus.

St. John and Worthen reported this species to be not uncommon in the Upper Coal Measures of Illinois, Nebraska, Kansas and Iowa. In Illinois it was reported from "above No. 9 coal," and in Iowa from Fremont and Mills counties, the horizon not given. Because we are able to establish the stratigraphic position of our specimens more closely than those previously reported, and because of the variety of fish remains recovered from this locality, some of which have been sent to the Museum of Science and Industry, Chicago, the recording of this occurrence seems desirable.

Our specimens were recovered from a zone 1½ feet above the Nodaway coal of the Wabaunsee group, 270 feet beneath the surface in the shaft located in the SW ¼, sec, 28, T. 69 N., R. 37 W.

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NEWBERRY, J. S., and WORTHEN, A. H., 1870, Description of fossil vertebrates: Illinois Geol. Survey Rept., vol. 4, p. 361, pl. 4, figs. 4, 5, 11.

NIELSON, E., 1932, Permo-Carboniferous fishes from East Greenland: Meddelelser om Grönland, Bd. 86, no. 3.

ST. JOHN, O., and WORTHEN, A. H., 1875, Description of fossil fishes: Geol. Survey Illinois, vol. 6, pp. 318–321, pl. 8, figs. 1–22.

JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 4, PP. 537–539, JULY 1951

NOMENCLATURAL NOTES

ZOOLOGICAL NOMENCLATURE: NOTICE OF PROPOSED SUSPENSION OF THE RULES

Volume 2 of the Bulletin of Zoological Nomenclature, published in April and May, 1951, includes applications for suspension of the Rules in connection with the following names which are of interest to paleontologists.

IN PART 3

All names for "Petrificata" in vol. 3 of Linnaeus, 1768, *Syst. Nat.* (ed. 12) and in corresponding portions of the following later editions of the above work: (a) Gmelin (J. F.), 1793, *Syst. Nat.* (ed. 13) vol. 3; (b) Houttuyn (M.), 1785, *Natuurlyke Historie*, vol. 3; (c) Turton (W.), 1806, *Gen. Syst. Nature*, vol. 7 (p. 66) (File 418).

Conchidium Oehlert, 1887, and *Pentamerus* Sowerby (J.) 1813 (Class Brachiopoda) (pp. 89–96) (File 286).

IN PART 6/8

Sphaeroceras Bayle, 1878 (Class Cephalopoda, Order Ammonoidea), proposed validation of, by suppression of *Sphaeroceras* Hope, 1840 (Class Insecta, Order Coleoptera) (pp. 164–166) (File 405).

Procerites Siemiradzki, 1898 (Class Cephalopoda, Order Ammonoidea) proposed designation of type species of (pp. 167–169) (File 403).

Macrocephalites Zittel, 1884 proposed designation of type species of; *Ammonites macrocephalus* Schlotheim, 1813, proposed determination of species to which name applicable (Class Cephalopoda, Order Ammonoidea) (pp. 170–172) (File 401).

Pictonia Bayle, 1878, and *Rasenia* Salfeld, 1913, proposed designation of type species of; trivial name *cymodoce* d'Orbigny, 1850 (as published in the binominal combination *Ammonites cymodoce*), (Class Cephalopoda, Order Ammonoidea), proposed suppression of (pp. 178–180) (File 421).

Aulacostephanus Tornquist, 1896 (Class Cephalopoda, Order Ammonoidea), proposed designation of type species of (pp. 188–190) (File 384).

Kosmoceras Waagen, 1869, *Harpoceras* Waagen, 1869, and *Perisphinctes* Waagen, 1869 (Class Cephalopoda, Order Ammonoidea), proposed designation of type species of (pp. 191–193) (File 445).

Planites de Haan, 1825, proposed suppression of; *Nautilus polygyratus* Reinecke, 1818 (Class Cephalopoda, Order Ammonoidea), determination of species to which name applicable (pp. 194–197) (File 402).

Planulites Lamarck, 1801, *Orbulites* Lamarck, 1801, *Pelagus* Montfort, 1808, *Ellipsolithes* Montfort, 1808, *Globites* de Haan, 1825 (Class Cephalopoda, Order Ammonoidea), proposed suppression of (pp. 198–199) (File 423).

Ammonites Bruguiere, 1789 (Class Cephalopoda, Order Ammonoidea), proposed suppression of (pp. 200–203) (File 425).

angulatus Schlotheim, 1820 (as published in the binominal combination *Ammonites angulatus*) (Class Cephalopoda, Order Ammonoidea), proposed validation of, and determination of species to which name applicable (pp. 204–207) (File 422).

Toxosphinctes Buckman, 1923 (Class Cephalopoda, Order Ammonoidea), proposed suppression of (in favour of *Arisphinctes* Buckman, 1924) (pp. 214–216) (File 389).

Arnioceras Hyatt, 1867 (Class Cephalopoda, Order Ammonoidea), proposed designation of type species of (pp. 217–219) (File 509).

Liparoceras Hyatt, 1867 (Class Cephalopoda, Order Ammonoidea) proposed designation of type species of (pp. 220–222) (File 507).

Normannites Munier-Chalmas, 1892 (Class Cephalopoda, Order Ammonoidea) proposed designation of type species of (pp. 222–223) (File 508).

virgula Deshayes, 1831 (as published in the binominal combination *Gryphaea virgula*) (Class Pelecypoda), proposed validation of (pp. 234–235) (File 407).

asper Lamarck, 1819 (as published in the binominal combination *Pecten asper*) (Class Pelecypoda), proposed validation of (pp. 236–237) (File 408).

Gryphaea Lamarck, 1801 (Class Pelecypoda), proposed suppression of, and validation of *Gryphaea* Lamarck, 1819 (pp. 239–240) (File 365).

Specialists are invited to comment on any of the foregoing applications in writing addressed to the Secretary to the International Commission (Mr. Francis Hemming, 28 Park Village East, Regent's Park, London N.W.1, England) as soon as possible. Comments should be clearly marked with the file numbers given above. In order to be considered by the Commission, comments must be received by the Secretary as follows: Part 3, October 20, 1951; Part 6/8, November 4, 1951.

NEW NAME FOR GENOTYPE OF *ALATACYTHERE* (OSTRACODA)

HENRY V. HOWE
Louisiana State University

The upper Eocene ostracode originally described under the name *Cythereis* (*Pterygocythereis*) *alexanderi* Howe & Law 1936 (p. 42, pl. 4, fig. 23; pl. 5, fig. 5) was subsequently selected as the genotype of *Alatacythere* Murray & Hussey 1942 (p. 169). It is a homonym of the Cretaceous ostracode species *Cythereis alexanderi* Morrow 1934 (p. 203, pl. 31, figs. 14a–c), and therefore needs renaming. Since the former species was named in honor of Dr. Charles Ivan Alexander, I propose *Alatacythere ivani* as a new name for it.

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MORROW, A. L., 1934, Foraminifera and Ostracoda from the Upper Cretaceous of Kansas: Jour. Paleontology, vol. 8, pp. 186–205, pls. 29–31.

MURRAY, GROVER, JR., and HUSSEY, K. M., 1942, Some Tertiary Ostracoda of the genera *Alatacythere* and *Brachycythere:* Jour. Paleontology, vol. 16, pp. 164–182, pls. 27, 28.

ON *PROTOJUNIPEROXYLON ARCTICUM*

OLOF H. SELLING
Naturhistoriska Riksmuseum, Stockholm, Sweden

In 1944 (p. 13) I described under the name of *Protojuniperoxylon arcticum* a species of fossil wood (roots) from Hope Island, Svalbard. It was believed to belong to the Cupressaceae; a detailed comparison showed numerous similarities. Professor R. Kräusel, who dealt with the find in his "Die fossilen Koniferen-Hölzer" (1949, p. 143), also found that the structure "weitgehend an die Wurzeln rezenter Cupressaceen erinnert." He continues:

> Soweit Sekundärholz entwickelt ist, weist dieses juniperoid getüpfelte Markstrahlenwände auf, während die radialen Tracheidentüpfel bald einbald zweireihig angeordnet sind, bald opponiert, bald wechselständig und sich gegenseitig ±abplattend, weite Teile der Tracheiden und dann Sterngruppen bildend und damit durchaus dem Bilde von *Protojuniperoxylon* entsprechend. Aber es handelt sich dabei immer um die ersten sekundären Zuwachszonen, und es fragt sich sehr, ob man diesen Befund als gültig auch für das ältere Wurzel- und das Stammholz ansehen darf. Ich habe an jungen Wurzeln von *Sequoia gigantea* (Lindl.) Decne und *Cryptomeria japonica* (L. f.) Don in den ersten Zuwachs-Zonen des Holzes ähnliche Strukturen beobachtet. . . .

When I referred the Hope Island roots to *Protojuniperoxylon* I was not aware of the fact that even closer similarities exist with certain Cycadeoideas, e.g., *C. dartoni* Wieland (1916, p. 95, pls. 41–50; wood: pl. 33, fig. 3, pl. 34, figs. 1, 2, pl. 35, fig. 6, and pl. 36, figs. 2, 3). I am indebted to Professor I. W. Bailey for kindly having drawn my attention to this. The paper by Stopes, "Roots in *Bennettites*" (1917), and certain data in Guttenberg's (1949) "Der primäre Bau der Gymnospermenwurzel" seemed to exclude the Cycadophyta. Dr. Bailey has informed me, however, that he has found the type of tracheary pitting occurring in the secondary xylem of these roots only in the *Cycadeoidea* and in *Trochodendron* and *Tetracentron* (see further, Bailey and Nast, 1945; also Lemesle, 1947). The rays and other characters seem to exclude the latter genera. The name *Protojuniperoxylon arcticum* should accordingly be dropped. The nomenclature of the Hope Island fossil roots remains to be settled by further comparison. Their reference to the Cycadeoidea does not in itself permit an exact age determination; the limits given by the local geology are the Upper Triassic and the Lower Cretaceous (Selling, 1944, pp. 1–2; 1945, pp. 44–46).

Cycadeoideas are mainly Lower Cretaceous, particularly Wealden.

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GUTTENBERG, H. VON, 1941, Der primäre Bau der Gymnospermenwurzel. In: Linsbauer, K.(†), Tischler, G., and Pascher, A., Handbuch der Pflanzenanatomie, II: 3, Bd. 8, pp. i–iv, 1–71. Berlin, Borntraeger.

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LEMESLE, R., 1947, Fibres aréolées chez certaines Apocarpales et divers aspects de trachéides du type cycadéen chez les Dicotylédones hétéroxylées: Acad. sci. Paris Comptes rendus, vol. 225, pp. 587–588.

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JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 4, PP. 540–541, JULY 1951

BIBLIOGRAPHIC NOTE

A FORGOTTEN BOOK AND ITS AUTHOR

G. WINSTON SINCLAIR AND MARY E. ROLLMAN
University of Michigan

Some time ago Mr. Eugene S. Richardson, Jr., brought to my attention a plaster-cast which had been received in the Chicago Natural History Museum, labelled "*Conularia doani*." I did not know of this species, nor could I find any reference to it, and assumed that it was a manuscript name. Later, in the U. S. National Museum, I found a similar cast, but this time labelled "*Conularia doani* Dennis." With this further clue, I was able to discover that the species had indeed been described, and some other fossils with it, in a book which seems to have escaped the bibliographers and indexers. Since its author lived all his life in Richmond, Indiana, I expected that he would be well known to such oldtimers as Dr. R. S. Bassler and Dr. W. H. Shideler. However, they could tell me nothing of him, and did not know of his book. That the book should be unknown to the leading students of the region surprised me, and made me realize the lostness of the book in a way which its omission from Nickles and the Library of Congress cards had not, and prompted this notice.

THE BOOK

An / Analytical Key / to the / fossils of the vicinity / of / Richmond, Ind. / By D. W. Dennis. / Teacher of Natural Science in the City High School. Richmond, Ind.: Daily Palladium Printing House. 1878. 15×12.5 cm. 63 pp. Bound in black cloth with title on cover: Key / to the Richmond Fossils. Frontispiece of two photographs mounted on either side of a sheet, with two pages of description, not numbered.

The book consists of nineteen sections viz.: "Preface," "Note," "Remarks on Strata," "Key to the Classes," "Key to the Plants," "Polyps," "Echinodermata," "Bryozoa," "Brachiopoda," "Pteropoda," "Gasteropoda," "Lamellibranchiata," "Cephalopods," "Ostracoids," "Annelids," "Trilobites," "Addenda," "Remarks on the life described in the preceding pages," "Index." Each of the systematic chapters is introduced by a set of the definitions necessary for understanding the synopses within it; each has a key to the genera, and a brief diagnosis of the genera and species. The "Polyps" include *Monticulipora* and *Stromatocerium*.

The new species described are: *Monticulipora indianaensis* (pp. 16–17), *Palaeaster parallelus* (p. 23), *Ptilodictya monticulifera* (pp. 25–26), *Conularia doani* (pp. 35–36) and *Raphistoma ? planispira* (p. 41). These (with the exception of *Palaeaster parallelus*) are illustrated in the photographs, as are *Aulopora arachnoidae* and *Ceramopora ohioensis*.

A second edition appeared under the title: A reprint of the tables / of an / Analytical key / to the / Fossils of Richmond, Ind. / published in 1878 / Nicholson & Bro. [Richmond] 1889. 48 pp., including title-page, one sheet of advertising, and four numbered blank pages for memoranda. It is paper-covered. This edition has a new prefatory note, but omits the original preface, note, remarks on strata, key to the classes, and the final remarks. The reprinted key is essentially unchanged, the only alteration of interest to us being the omission of *Monticulipora indianaensis*. In its place two other species are included (of Nicholson) and presumably Dennis had abandoned his species. This edition does not have the plates of photographs.

What value these species may have I would not like to guess without seeing the specimens. *Palaeaster parallelus* is so briefly described that it is not distinguishable, but if the holotype is in existence it might be validated by redescription. *Conularia doani* is a synonym of *C. formosa* which was also described in 1878, but a few months earlier.

THE AUTHOR

David Worth Dennis was born in 1849

on his father's farm near Dalton, Indiana, and died at Richmond in 1916. His life, except for very brief excursions, was passed in his own section of his own state, and within this little world he was respected and esteemed as a leader in educational and scientific matters. He was graduated B.A. at Earlham College in 1873, M.A. in 1878. He took his Ph.D. at Syracuse in 1886. After a series of short appointments in the Richmond High School, Wilmington College and Bloomingdale Academy, he returned to Earlham and remained there as Professor of Natural Sciences for thirty-two years.

As is fitting in a Science Professor in a small college, his interests were wide, and his enthusiasms real, even when transitory. His presidential address to the Indiana Academy of Science, 1900, was on the techniques and possibilities of photomicrography. He was a leading member of the Audubon Society, and published some notes on birds. He published a chemistry manual, and an essay on the Bible and Nature. From reading his works, and the tributes paid him by former students, one gets a picture of a typical, and perhaps ideal, small-college professor. Enthusiastic and inspiring, he never became sufficiently a specialist to lose the ability to touch the ordinary student, never became bored with the commonplace miracles through which the naive may be touched.

Dennis seems to have thought much about fossils, and read a number of papers to the Indiana Academy dealing with them, but his work was not published and is now lost.

ACKNOWLEDGMENT

Although the physical writing of this note was done by Sinclair, I have had such assistance from Miss Rollman that she should appear as joint author, in spite of her protest that librarians are used to doing all the work without any credit, and that it would be disrupting to have the pattern broken.

Copies of this book were generously provided by the Library of Earlham College, Richmond, Indiana.

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Portrait: Indiana Acad. Sci. Proc., 1934, vol. 44, p. 28.

NOTICE

PALAEONTOLOGICAL SOCIETY OF JAPAN

The Palaeontological Society of Japan will be glad to receive applications for membership from foreign paleontologists. The dues are U. S. $2.00 per year. The Transactions and Proceedings of the Society are being revived after a lapse of ten years and present plans call for the publication of one annual number. The address of the Society is Geological Institute, University of Tokyo, Hongo, Bunkyo Ward, Tokyo, Japan. A limited number of application blanks and copies of the constitution may be obtained upon request from J. Marvin Weller, Walker Museum, University of Chicago, Chicago 37, Illinois.

JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 4, PP. 542–543, JULY 1951

REVIEWS

A REVISION OF FOSSIL *Sequoia* AND *Taxodium* IN WESTERN NORTH AMERICA BASED ON THE RECENT DISCOVERY OF *Metasequoia*, by Ralph W. Chaney. Am. Philos. Soc. Trans., n.s., vol. 40, pt. 3 (1950), pp. 171–263, 12 pls. Philadelphia, 1951. $1.50.

Ten years ago the Japanese paleobotanist Shigeru Miki erected the new genus *Metasequoia* (dawn redwood) for beautifully preserved Pliocene fossils from Japan referable to two species heretofore treated under *Sequoia*. Three years later, trees belonging to a new species of conifer were found by Tsang Wang in Szechuan, China. Two other Chinese botanists, Hu and Cheng, recognized that these trees belong to the new genus *Metasequoia* and later (1948) described the new species as *M. glyptostroboides*. When news of this discovery reached the United States shortly after the war, financial aid was sent by Prof. E. D. Merrill, Arnold Arboretum, Harvard University, who received the first good collections in 1947 and ample seed in January of 1948. Intrigued by this material and cognizant of the importance of this discovery, Professor Chaney visited China early in 1948 to study the dawn redwood in its natural environment. Since then he has examined thousands of fossil specimens of *Sequoia* and *Taxodium* from western North America and other boreal areas in an effort to segregate all material referable to *Metasequoia* and to redefine the two genera with which it had been confused for such a long time. The present study is the outgrowth of this critical revision, on the basis of which the known geological age and past distribution of the genus have been greatly extended. As a result, *Metasequoia* can now be regarded as the most abundant and widely distributed genus of the Taxodiaceae in North America from the Upper Cretaceous to Miocene. It is, however, absent from younger strata of the American record, but known from the Pliocene of Japan and today is represented by several hundred trees growing in China.

The confusion surrounding the fossils now assignable to three genera dates back nearly one hundred years. The convincingly documented story of this long and unbroken series of mistakes as reported by Professor Chaney is a remarkable example of the perpetuation of scientific errors. The meticulous and unhesitating exposure of these errors, committed by a number of early and living paleobotanists including the author himself, provides reading at least as dramatic as the report of the "discovery" of the living dawn redwood. All in all, Professor Chaney now recognizes for the area selected and the time involved five species in three genera: *Metasequoia occidentalis* (Newberry) new comb., *M. cuneata* (Newberry) new comb., *Sequoia affinis* Lesquereux and *S. dakotensis* Brown, and *Taxodium dubium* (Sternberg) Heer. The possibility of biological identity of the Tertiary species, *M. occidentalis*, with the living species, *M. glyptostroboides* Hu & Cheng, is fully discussed. The two fossil species of *Metasequoia* accepted by Chaney were originally described by John S. Newberry under *Taxodium*. These names are retained in new combinations in recognition of Newberry's keen understanding of these fossils nearly one hundred years ago. Fittingly Professor Chaney dedicated the entire study to the memory of John S. Newberry.

THEODOR JUST

CALIFORNIA FOSSILS FOR THE FIELD GEOLOGIST, by Hubert T. Schenck and A. Myra Keen. Stanford University Press. 1950. $2.00.

ILLUSTRATED CATALOGUE OF JAPANESE TERTIARY SMALLER FORAMINIFERA, by Kiyoshi Asano. Tokyo, Hosokawa Printing Co. 1950.

These are both handbooks designed to aid the practical paleontologist in the identification of fossils. The first, consisting of 88 pages in a ring binder, is of pocket size and consists of 56 plates, illustrating mainly Tertiary species, a bibliography and indexes arranged biologically, stratigraphically and by specific

names. It is a reissue of a similar booklet privately printed in 1940.

Two numbers (2 and 3) of the second publication have been received. These are concerned with the Buliminidae, 19 pages; Textulariidae, six pages, Valvulinidae, four pages; and Verneuilinidae, four pages. Each page, printed on only one side, consists of reproductions of three 3×5 inch cards with illustrations, references and descriptions. Most of the known Japanese species are included and a few new species are proposed.

J.M.W.

STRATIGRAPHY AND SEDIMENTATION, by W. C. Krumbein and L. L. Sloss. San Francisco, W. H. Freeman and Co. 1951. 497 pp.

This is an interesting and unusual book. The title, however, does not adequately indicate its contents because it is not devoted to either conventional stratigraphy or sedimentation. It is, rather, an exposition of one type of sedimentological approach to paleogeography through regional stratigraphy. To be more specific, it is a presentation in textbook form, with necessary background material, of the system of gross sedimentary analysis described by Krumbein, Dapples and Sloss in a recent volume of the A.A.P.G. Bulletin (vol. 32, pp. 1909–1947). One may disagree more or less with some features of the authors' methods and conclusions, but the book remains a stimulating one that should interest all stratigraphic geologists and many paleontologists. Also, it will be found a very useful and broadening reference for any college course in stratigraphy.

J.M.W.

ON THE ORIGIN OF SPECIES BY NATURAL SELECTION, by Charles Darwin. Reprint: Philosophical Library, 1951. $3.75.

This is a reprint of the first edition of 1859. All previous reprints have reproduced later editions, which include various changes and additions made to meet the objections of early critics. For the first time modern readers are able to obtain Darwin's famous book as he originally wrote it.

J.M.W.

JOURNAL OF PALEONTOLOGY, VOL. 25, NO. 4, PP. 544–552, JULY 1951

SOCIETY RECORDS AND ACTIVITIES

REPORTS AND MINUTES OF THE TWENTY-FIFTH ANNUAL MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

The twenty-fifth annual meeting of the Society of Economic Paleontologists and Mineralogists was held at the Jefferson Hotel in St. Louis, Missouri, April 24–26, 1951, in conjunction with the annual meeting of The American Association of Petroleum Geologists.

The Presidential Address of the Society, "Some relations among sedimentation, stratigraphy, and seismic exploration," was given by W. C. Krumbein in the joint session on Tuesday, April 24.

The first part of the technical program of the Society, with H. B. Stenzel and A. G. Unklesbay presiding, began at 9:00 A.M., Wednesday, April 25, and continued until 12 noon. The following papers were presented.

A. K. Miller, "Comparison of African and American Tertiary nautiloid faunas"

L. R. Laudon, J. M. Parks, and A. C. Spreng, "New crinoid fauna from Banff formation, Mississippian, Sunwapta Pass area, Alberta"

M. K. Elias, "Moeller's error in identification of Ehrenberg's *Alveolina montipara*, and the consequences"

James A. Peterson, "Ostracoda from lower Sundance formation, western interior United States"

Frederick M. Swain and James A. Peterson, "Ostracoda from 'Upper Sundance', western interior United States"

Charles W. Pitrat, "Coral fauna of biostrome in Cedar Valley limestone"

Doris Nodine Zeller, "Endothyroid Foraminifera and ancestral fusulinids from type Chesteran (Upper Mississippian)"

Mitchell A. Light, "Stratigraphic relationships of illite and glauconite in coastal plain of New Jersey"

William H. Mathews, "Some aspects of reef paleontology and lithology in Edwards formation of Texas"

Keith Young and Edward Marks, "Zonation of Austin group, Williamson County, Texas"

Sherman A. Wengerd, "Lithology and stratigraphy of Hermosa bioherms, San Juan Canyon, Utah"

A session on statistical and numerical data from components of sedimentary rocks, with K. O. Emery and Jack L. Hough presiding, was presented from 1:30 to 4:00 P.M., Wednesday, April 25. The following papers were given.

W. C. Krumbein, "Use of statistical techniques in paleontology, sedimentation, and stratigraphy"

Benjamin H. Burma, "What is quantitative paleontology?"

Leo M. Wright, "Statistical study of Paleozoic ostracode *Amphissites centronotus*"

L. M. Cline, "Ecological control in some Pennsylvanian marine invertebrate faunas"

Laurence H. Lattman, "Presentation of petrofabric diagrams"

E. C. Dapples, "Petrographic and lithologic attributes of sandstones"

H. R. Gault; Ross H. Lessentine and Carl Warmkessel, "Correlation of carbonate rocks by chemical analysis"

Douglas L. Inman, "Suggested standardization of descriptive parameters in mechanical analysis of sediments"

The third part of the technical program, with Harold W. Scott and E. C. Dapples presiding, was presented from 9:00 A.M. to 12 noon, Thursday, April 26. The following papers were read.

Symposium on Paleoecology of Shale and Evaporite Deposition

Shepard W. Lowman, "Relationship of biotic and lithic facies in Recent Gulf Coast sedimentation"

Parker D. Trask, "Depositional environment of black shale"

Ralph E. Grim, "Depositional environment of red and green shales"

L. L. Sloss, "Significance of evaporites in depositional sequence"

Samuel P. Ellison, Jr., "Microfossils as environment indicators in marine shales"

The following papers were presented in a

general session from 1:30 to 3:50 P.M., Thursday, April 26, with Thomas H. Philpott and Gordon Rittenhouse presiding.

Donald F. Saunders, "Thermoluminescence and surface correlation of limestones"

James M. Parks, Jr., "Thermoluminescence as a tool for subsurface correlation"

Edward J. Zeller, "Thermoluminescence as a means for relative age determination of limestones"

A. G. Unklesbay, "Exposed Devonian rocks of central Missouri"

Warren O. Thompson, "Crinkled limestones in Lykins formation of Colorado"

F. D. Holland, Jr., "Stratigraphic details of Lower Mississippian rocks of northeastern Utah and southwestern Montana"

Daniel J. Jones, "New teaching aid in sedimentation"

The following papers were presented by title.

Raymond C. Douglass, "Some Pennsylvanian and Permian fusulines from northeastern Nevada"

W. D. Keller, Donald L. Biggs and John H. Spotts, "Infrared spectra of some pulverized common rock-forming minerals"

John P. Brand, "Fauna of Leipers formation, Russell County, Kentucky"

W. D. Keller and Ellen Markward, "Feldspars in sandstones"

The meeting adjourned at 3:50 P.M.

The annual business session of the Society was called to order at 3:55 P.M., Thursday, April 27, by W. C. Krumbein, president.

The minutes of the 1950 meeting were approved as published in the *Journal of Paleontology*, vol. 24, no. 4 (July, 1950).

The following reports were given.

1. *Report of the Committee on Members and Papers (Hollis D. Hedberg, Chairman).*—As of April 15, 1951, the Society had reached a new high of 809 members and associates plus 54 applications not yet completely processed. Growth during the last few years is shown in table 1. Noteworthy is the fact that since the inception of the committee in March, 1948, the Society has essentially doubled in size.

Regional representatives of the Committee on Members and Papers, and growth of membership in individual districts during 1950–51 are shown in table 2.

Membership growth in the States during the year on a percentage basis has been particularly noteworthy in the Appalachian, Rocky Mountain, and New York districts. The Oklahoma-Arkansas-North Louisiana district which set a high record for increase last year has maintained a high rate for this year also.

The increase in foreign membership is outstanding—there now being 161 members (full and associate) outside of the United States and 24 additional foreign applications not yet processed. This increase is the more remarkable considering the difficulties confronting many foreign members in securing dollar exchange. Several foreign members have had to arrange for payment of their dues through book dealers who are able to handle the exchange problem. Obviously also the Society's publications are read by many geologists and paleontologists in foreign countries who obtain them through dealers, libraries, or other institutions, but

TABLE 1

	March 1948	*March 1949*	*March 1950*	*Feb. 15 1951*	*April 15 1951*
Members	319	377	473	557	569
Associates	101	144	192	220	240
Total	420	521	665	777	809

Approved but not yet paid (April 15, 1951)

Members	3
Associates	29

Being processed (April 15, 1951)

Members	9
Associates	13
Total members and applications, April 15, 1951	863

TABLE 2

District	*Regional Representative*	*Members March 1950*	*Members Apr. 15, 1951*	*Applications Apr. 15, 1951*
Pacific Coast	H. Driver	111	120	7
Rocky Mountain	J. H. Johnson	25	34	2
Tex., Ariz., New Mex., S. La.	J. A. Waters	169	189	6
Okla., Ark., North La.	M. P. White	67	85	1
Wichita	H. A. Ireland	19	24	1
Great Lakes	H. Lowenstam	62	62	8
Appalachian	E. M. Spieker	20	32	2
Southeast Gulf	D. Gravell	20	18	0
Capital	L. Henbest	34	36	1
New York	J. Martens	27	36	1
New England	H. C. Stetson	11	12	1
Canada	F. G. Fox	12	15	0
Venezuela	A. Dusenbury	25	26	0
Other Foreign:	B. Ellis, H. Hedberg, H. Thalmann	63	120	24
Total		665	809	54

who are not members. Thus in the case of England, for example, the Society has only eight members but 35 additional non-member subscriptions.

We believe that the increasing international scope of the Society as indicated by its membership list represents a very desirable trend and that the publication in the *Journals* of worthwhile papers from foreign authors will also have a desirably broadening effect on the Society as a whole. We recognize at the same time that the increased foreign membership complicates both the business and editorial operations of the Society and we particularly appreciate the extra burden which even the present addition of foreign members has placed on the headquarters office.

With regard to papers, we understand that the editors of both *Journals* have, to say the least, an adequate supply at the present time. No particular effort has been made, therefore, to drive for additional contributions and I believe the committee has functioned in this respect only in attempting to steer particularly worthwhile contributions toward the Society's publications.

The chairman wishes to express his appreciation of the very fine cooperation received from members of the committee and the officers of the Society. He also wishes to stress his firm belief that the Society has not yet closely approached its membership capacity and that further marked growth can undoubtedly be achieved.

2. *Report of the Editor of the Journal of Paleontology* (*J. Marvin Weller*).—Volume 24 of the *Journal of Paleontology*, issued in conjunction with the Paleontological Society in 1950, contains 762 pages and 90 collotype plates. Published in it are 45 paleontological papers, 5 articles on nomenclature and taxonomy, 1 each devoted to bibliography, a range chart, fossil environments and a grinding instrument, 16 paleontological notes, 17 nomenclatural notes, 9 reviews, data relating to the memberships and activities of the two societies, and other miscellaneous material.

The March, July, and November numbers were prepared by your editor on behalf of the Society of Economic Paleontologists and Mineralogists. These numbers consist of 402 pages and 39 collotype plates, an increase of 30 pages and a reduction of 6 plates as compared with the previous volume. The contributions in these numbers may be classified as follows:

	Paleozoic	*Mesozoic*	*Cenozoic*
Paleobotany	1		
Foraminifera	1	1	3
Corals			1
Blastoids	1		
Conodonts	1		
Brachiopods	1		
Cephalopods	2		
Trilobites	1		
Eurypterids	2		
Ostracodes	1		1

Three of these papers are concerned with fossils from foreign countries. In addition are a symposium of 4 papers on fundamentals in paleontology, 2 articles on taxonomy, 1 each devoted to Australian Tertiary microfaunas, a range chart, fossil environments, a grinding instrument, a bibliography, 5 paleontologic notes, 9 nomenclatural notes and 8 reviews.

Manuscripts continue to be received at a rate in excess of that at which they can be published and at present an undesirably large backlog of good papers is in hand.

3. *Report of the Editor of the Journal of Sedimentary Petrology* (*Jack L. Hough*).—The Council of S.E.P.M., at its annual meeting in April, 1950, authorized the expansion of the *Journal of Sedimentary Petrology* to four issues per year and to a maximum of 64 pages per issue. Accordingly, a new publication schedule was set up, with numbers to appear in March, June, September, and December of each year. A June, 1950, number initiated this schedule.

Volume 20, for the year 1950, was composed as follows:

No. 1, April:	60 pages text plus 4½ pages of advertising
No. 2, June:	59 pages text plus 2½ pages of advertising
No. 3, Sept.:	61 pages text plus 3½ pages of advertising
No. 4, Dec.:	49 pages text plus 4½ pages index, plus 2½ pages advertising
Total	229 pages text plus 4½ pages index, 13 pages advertising

The expansion of the *Journal* has brought publication essentially up to date. A two-year backlog of papers was reduced to a one-year backlog by the Council's authorization last April. By December, 1950, there were sufficient papers on hand to fill only the succeeding (March, 1951) issue. It appeared at that time that the *Journal* might have to be reduced to less than the authorized number of pages per issue.

At the present time, however, there is a satisfactory balance between rate of receipt of acceptable manuscripts and the publication rate. The March, 1951, number has been published, the technical papers for the June, 1951, issue are in the hands of the publisher, and there are sufficient papers on hand to fill the September issue. All of these issues will contain approximately 60 pages each of technical material.

Volume 20 (1950) contains 21 technical papers with an average length of ten pages. Seventeen of these papers were written by Americans, and the other four were written by Australian, Dutch, French, and Japanese authors.

The national origin of papers published in Volume 21, Number 1 (March, 1951), and of papers on hand for publication in 1951 are as follows:

50 per cent (11) American; 22 per cent (5) Dutch; 23 per cent British Commonwealth, i.e., 9 per cent (2) English, 9 per cent (2) Australian, 5 per cent (1) New Zealand; and 5 per cent (1) Egyptian.

This represents an absolute increase in the number of non-American papers and a definite decrease in American papers received during the last several months, as compared with previous year's publication. It is possible that the decline in receipt of American papers is a reaction to the situation which existed a year ago, that of a two-year backlog with consequent long delay in publication. At present the interval between receipt of a paper and its publication is about eight months.

4. *Report of the Secretary-Treasurer* (*Cecil G. Lalicker*).—

BACK VOLUME SALES

Back volumes of the Journal of Paleontology	$2,796.75
Back volumes of the Journal of Sedimentary Petrology	472.02

PRINTING AND ENGRAVING BILLS FOR 1950

Journal of Paleontology

	Banta Printing Bills	*Meriden Engraving Bills*	*Total Printing and Engraving Bills*	*S.E.P.M. Total Printing and Engraving Bills*
Number 1 (January)*	$ 1,767.36	$ 707.28	$ 2,474.64	
Number 2 (March)	2,009.54	571.10	2,580.64	$2,580.64
Number 3 (May)*	1,645.11	459.00	2,104.11	
Number 4 (July)	1,727.64	417.71	2,145.35	2,145.35
Number 5 (September)*	1,560.37	468.20	2,028.57	
Number 6 (November)	1,720.53	319.59	2,040.12	2,040.12
	$10,430.55	$2,942.88	$13,373.43	$6,766.11
(1949 Totals)	($ 9,554.05)	($3,224.51)	($12,778.56)	($6,464.66)

* Odd numbers paid by Paleontological Society.

Journal of Sedimentary Petrology

Number 1 (April)	$ 916.41
Number 2 (June)	835.13
Number 3 (September)	843.72
Number 4 (December)	948.24
	$3,543.50
(1949 Total)	($1,912.10)

MEMBERSHIP, MAILING, AND JOURNAL STATISTICS

	March 1951	*March 1950*	*March 1949*
1. S.E.P.M. Membership:			
Active Members	563	478	380
Associate Members	229	193	146
Honorary Members	1	1	—
Correspondents	5	5	—
TOTAL	798	677	526
2. Journal of Paleontology Mailing List:			
S.E.P.M. Active Members	362	319	261
S.E.P.M. Associate Members	130	110	84
Subscribers	519	505	497
P.S. Members	443	390	393
TOTAL	1,454	1,324	1,235
3. Journal of Sedimentary Petrology Mailing List:			
S.E.P.M. Active Members	337	279	209
S.E.P.M. Associate Members	133	98	66
S.E.P.M. Correspondents	5	5	—
Subscribers	449	413	422
TOTAL	924	795	697

4. Number of pages in 1950 Journal of Paleontology	762 (700, 1949)
5. Number of plates in 1950 Journal of Paleontology	90 (103, 1949)
6. Total edition of 1950 Journal of Paleontology	1,700 (1500, 1949)
7. Number of pages in 1950 Journal of Sedimentary Petrology	231 (138, 1949)
8. Total edition of 1950 Journal of Sedimentary Petrology	1,200 (900, 1949)
New Members from March 1, 1950, to March 1, 1951	69 (97, 1949–1950)
New Associates from March 1, 1950, to March 1, 1951	90 (57, 1949–1950)
Transfer to Active Membership, March 1, 1950, to March 1, 1951	36 (5, 1949–1950)
Reinstatement to Active Membership, March 1, 1950, to March 1, 1951	1 (5, 1949–1950)

FINANCIAL STATEMENT FOR THE YEAR ENDED DECEMBER 31, 1950

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
CERTIFICATE OF CERTIFIED PUBLIC ACCOUNTANTS

To the Council,
Society of Economic Paleontologists and Mineralogists:

We have examined the balance sheet of Society of Economic Paleontologists and Mineralogists at December 31, 1950 and the related statement of income and surplus for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying balance sheet and statement of income and surplus present fairly the financial position of Society of Economic Paleontologists and Mineralogists at December 31, 1950 and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

ARTHUR YOUNG & COMPANY

Tulsa, Oklahoma
January 22, 1951

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
BALANCE SHEET
AT DECEMBER 31, 1950

ASSETS

CURRENT ASSETS:		
Cash		$11,074.75
Savings account		2,369.29
Accounts receivable (less reserve, $50.79)		520.81
Total current assets		$13,964.85
PUBLICATIONS:		
Journals of Paleontology:		
Issues prior to 1950—19,394 at $.50 each (3,184 complete volumes)	$ 9,697.00	
Issues 1 to 6 of 1950—930 journals, at cost	1,187.31	
Reprints in 1948, Volume 1, 1927—847 volumes, at cost	1,870.00	
Journals of Sedimentary Petrology:		
Issues prior to 1950—2,229 journals at $.50	1,114.50	
Issues 1 to 4 of 1950—977 journals, at cost	706.70	14,575.51
FURNITURE AND FIXTURES (less reserve, $539.43)		1.00
DEFERRED CHARGES		14.90
		$28,556.26

LIABILITIES AND SURPLUS

CURRENT LIABILITIES:		
Accounts payable		$ 2,439.23
Amount payable to Paleontological Society		2,222.59
Total current liabilities		$ 4,661.82
DEFERRED INCOME:		
Subscriptions to journals (less $1,233.78 payable to Paleontological Society)	$ 3,456.26	
Membership dues for 1951 and 1952	3,141.10	6,597.36
SURPLUS (per accompanying statement)		17,297.08
		$28,556.26

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
STATEMENT OF INCOME AND SURPLUS
FOR THE YEAR ENDED DECEMBER 31, 1950

INCOME:		
Membership dues and subscriptions:		
Journals of Paleontology and Sedimentary Petrology	$ 2,028.00	
Journal of Paleontology	7,459.80	
Journal of Sedimentary Petrology	3,477.42	$12,965.22
Sales of back numbers:		
Journal of Paleontology, Volume 1, 1927	$ 140.70	
Journal of Paleontology, Volumes 2 to 24	2,803.35	
Journal of Sedimentary Petrology	444.92	3,388.97
Sales of plates		292.29
Advertising		308.05
Miscellaneous		126.72
		$17,081.25
Less: Proportion of 1950 income accrued to Paleontological Society		1,950.35
		$15,130.90
COST AND EXPENSES:		
Cost of printing:		
Journal of Paleontology	$ 6,904.50	
Journal of Sedimentary Petrology	3,315.37	
	$10,219.87	
Clerical salaries	2,137.50	
Office supplies and expense	316.70	
Postage and express	609.79	
Office rent	768.00	
Insurance and bond	46.79	
Audit fee	100.00	
Taxes	38.47	
Miscellaneous	141.03	
	$14,378.15	
Adjustment for increase in inventory of publications	(454.13)	13,924.02
NET INCOME		$ 1,206.88
SURPLUS AT DECEMBER 31, 1949		16,090.20
SURPLUS AT DECEMBER 31, 1950		$17,297.08

5. *Report of the Research Committee (H. W. Scott, chairman).*—The reorganized Research Committee is composed of S. W. Lowman (1 year), R. V. Hollingsworth (1 year), E. C. Dapples (3 years), R. W. Rolshausen (3 years), H. W. Menard, vice-chairman (2 years), H. W. Scott, chairman (1 year).

The committee met in St. Louis on April 25. Others in attendance were K. O. Emery, J. L. Hough, H. A. Ireland, W. D. Keller, R. D. Russell, J. M. Weller and Gordon Rittenhouse.

The functions of the Research Committee were discussed to some considerable extent. It was felt that the primary function of the committee is to foster and encourage research. The means of carrying out this primary function are not yet clearly understood, and considerable discussion should be carried out by all members of the committee. We are seeking ways of being of greater service to the society and our profession.

The question of publication of abstracts of theses in mimeographed form was briefly discussed. No decisions were reached.

The question of establishing several awards was discussed but no decision was reached. Two classes of awards were mentioned: (1) those on the student level, and

(2) those on the professional level. Monetary awards are not necessarily the most desirable, but several of us feel the lack of recognition granted research students in our profession in contrast to the abundance of awards in other professions. It was felt that the value of awards is very great. Some definite recommendation will be made to the Council upon this matter prior to, or at the time of, the Los Angeles meeting.

A suitable program for the S.E.P.M. symposium to be held in Los Angeles was also discussed.

Suggestions are invited from the membership upon any phase of the committee's activities.

6. *Presidential Summary* (*W. C. Krumbein*).—President Krumbein briefly reviewed the Society's progress during the past year, touching upon significant developments as brought out by the report of the secretary-treasurer and of the standing committees. The reorganization of the Research Committee under the chairmanship of H. W. Scott, was stressed as an opportunity for the Committee to expand its functions. The establishment of a Revolving Publication Fund was also announced, based upon a loan from the Executive Committee of the American Association of Petroleum Geologists, which will permit publication of the Symposium on Turbidity Currents sponsored by the Research Committee in 1950. Returns from the sale of this first special paper will be used to help establish a continuing publication fund.

7. *Report of the Committee on Cooperation with the American Museum of Natural History* (*H. B. Stenzel, chairman*).—The committee recommends that a drive be made for a special fund. Also, it is recommended that this special fund be used for longer papers in paleontology to be printed in a series separate from the regular issues of the Journal of Paleontology.

8. *Report of the Pacific Section.*—The present California membership of the Pacific Section of the S.E.P.M. totals 109, with a mailing list of 126. Of these, 68 are members of the S.E.P.M.; the remainder are members of the American Association of Petroleum Geologists and the Paleontological Society.

Balance in the treasury at the time of this report is $229.92. These funds were secured by charging each member $1.00 and by the sale of syllabus on a field trip. The funds are used for mailing expenses in sending out announcements, meals for speakers, and a public address system for field trips.

The Section has arranged the following programs during the past several months.

November 17, 1950.—R. Stanley Beck, consultant, "Tertiary correlations of the San Joaquin Valley and adjacent areas"

January 26, 1951.—Fred B. Phleger, Jr., Scripps Institution of Oceanography, "Recent advances in the ecology of Foraminifera"

February 16, 1951.—Orville L. Bandy, University of Southern California, "Trends in foraminiferal research"

March 28, 1951.—Merle C. Israelsky, U. S. Geological Survey, "Oscillation chart, facts and fiction"

An annual two-day meeting and field trip is held jointly with the A.A.P.G. Pacific Section. The S.E.P.M. members arrange all details, including the mailing of announcements to all A.A.P.G. members, who constitute the majority of the attendance. This year the meeting is planned for May 11 and 12. The program opens with a dinner meeting in Bakersfield on Friday, May 11. A symposium on the Cuyama Valley is planned for this meeting under the guidance of three speakers, Ted Bear, Kenneth Krammes and Aden Hughes. On Saturday morning the group will drive from Bakersfield to the Cuyama Valley where the Richfield Oil Corporation geologists and paleontologists will lead a caravan of cars through the valley on a four- or five-hour trip ending with a picnic lunch. An attendance of 150–200 is expected for the dinner meeting and approximately 300 for the field trip.

It was moved by M. A. Hanna, seconded, and approved that all of the foregoing reports be accepted.

It was moved by R. Dana Russell, seconded, and approved, that the following resolutions be adopted:

BE IT RESOLVED that in behalf of the Society we extend an expression of our sincere thanks to the following.

TO H. W. Scott, chairman of the Research Committee, and the members of his committee, for the excellent research symposium for the 1951 annual meeting in St. Louis;

TO Hollis D. Hedberg and his Committee on Members and Papers for their very excellent continued service in obtaining material for publication in the *Journals* and for securing increasing numbers of new members for the Society;

TO W. D. Keller, chairman, and the members of the S.E.P.M. Technical Program for the high quality of the papers secured for the 1951 program;

TO the A.A.P.G. Executive Committee for praiseworthy management of the 1951 annual meeting;

TO the Jefferson Hotel for the very satisfactory manner in which it has provided facilities for the 1951 meeting; to the St. Louis Convention Bureau for the efficient handling of registrations; and to the Housing Bureau for finding satisfactory accommodations for our members.

The results of the election of officers by mailed ballot, for the new year, were announced by outgoing President William C. Krumbein as follows: President, Thomas H. Philpott; Vice-President, K. O. Emery; Secretary-Treasurer, Cecil G. Lalicker.

The following new business was transacted with President Philpott presiding.

It was moved by R. Dana Russell, seconded, and approved, that the Society contribute the sum of $50 to the American Geological Institute in response to the Institute's request for donations.

It was moved by Jack L. Hough, seconded, and approved that a vote of thanks be given to the officers of the Society for their excellent work during the past year.

The business session adjourned at 5:00 P.M., Thursday, April 26, 1951.

The McLean Card Catalogue of American Foraminifera

Species Index Cards of Foraminifera Available in Units of 50 cards at $5.00 per Unit

STILL AVAILABLE—Units #1 through #4 at $5.00 per unit, or may be purchased as one single item for $20.00 for all four units. An index to species is included with Unit #4, along with taxonomic notes on certain species.

Available after July 30, 1951—Unit #5—Significant Claiborne Eocene Foraminifera from the Gulf Coast. . . . . 50 cards.

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(These are limited editions in very short supply)

Foraminiferal Guide Fossils of the Atlantic Coastal Plains Region Between New Jersey and Georgia. (Blackline charts) . . . . . $3.00 per set Postpaid.

Later Tertiary Foraminiferal Zones of the Gulf Coast (20 large sheets of data on Miocene-Oligocene Foraminiferal Zones, Lithographed) . . . . . $7.50 per copy, Postpaid.

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JOURNAL OF PALEONTOLOGY

VOLUME I (1927), REPRINTED 1948

The Society of Economic Paleontologists and Mineralogists announces a special sale of Volume I of the *Journal of Paleontology* for a limited time only. This reprinted volume, consisting of more than 300 pages of text and line figures and 49 half-tone plates, contains papers on Foraminifera, Ostracoda, Diatomacea, Cephalopoda, and other fossils—as well as articles on correlation, stratigraphy, and sedimentology.

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W. H. TWENHOFEL, Orlando, Fla. (consulting editor) for mineralogy.

JACK L. HOUGH, Urbana, Ill. (editor) for mineralogy.

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Ex-Presidents

W. P. WOODRING, Washington, D. C., 1948.
WINIFRED GOLDRING, Albany, N. Y., 1949.
CHARLES E. WEAVER, Seattle, Wash., 1950.

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Sponsored by the Society of Economic Paleontologists and Mineralogists, The Paleontological Society, and the Society of Vertebrate Paleontology in support of the International Commission on Zoological Nomenclature.

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Address all communications to the chairman, G. WINSTON SINCLAIR, University of Michigan, Ann Arbor, Mich.

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